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CORRECTIONS

Volume 61, October 1933, page 314: Last line in table, "Hawaii" should be "Puerto Rico"; page 317, "Middle Slope", the mean temperature should be "58.7."

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

VOL. 61, No. 12
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DECEMBER 1933

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CORRELATION PERIODOGRAM INVESTIGATION OF ENGLISH RAINFALL

By DINSMORE ALTER

[University of Kansas, Lawrence, Kans., December 1933]

English rainfall was chosen for examination because, (*a*) the records are much longer than those of the United States, (*b*) preliminary studies had indicated the possibility of definite positive results by cycle analysis.

In 1929 the writer was sent to England as fellow of the John Simon Guggenheim Memorial Foundation to gather and to analyze rainfall records of that country. Through the courtesy and cooperation of officials of the British Meteorological Service he gathered from the manuscript records of the Rainfall Office a continuous record of the 203 years 1727–1929. In choosing records, the length of record and all notes regarding the manner in which it was kept were considered. Dr. Brooks and Dr. Glasspoole from their familiarity with the subject gave him very much valuable information that improved the results greatly. A desk in the office was given to the writer during the weeks spent in copying and each one with whom he came in contact seemed to strive to make him feel welcome.

The detailed records of the individual stations would be too long to publish here. Table 1 exhibits the stations used and the years for which monthly totals were available. Edinburgh in southeastern Scotland was included with the English stations because of its extremely long record.

In the case of each station the mean value of the record was secured for each month and from these means a table of percentages of normal was formed. Such a procedure weights stations equally for the years used. From these percentages a combined table was made of quarter yearly values, table 2. These are given graphically as figure 1. In it, the first quarter of a given year begins with December of the preceding year. Such quarters match better with the astronomical, meteorological and agricultural quarters than do those of the calendar.

Any long period variations of length much more than 20 or 30 years will be partly damped for the record of the eighteenth century because of the necessary inclusion of records as short as 13 years. No such damping exists for the nineteenth and twentieth centuries. It is important to stress this because of negative evidence regarding long swings such as the Brückner cycle.

Wherever notes showed a significant change in the exposure of the gage, means were taken for the separate exposures. In this connection it is interesting to note that at Exeter the same gage apparently has been used on the top of a wall throughout the whole record. Such an exposure is not the standard one but a uniformity is secured that is invaluable in this type of work. It is hoped that if a change ever is necessary several years of overlapping records of new and of old exposures will be made. Although the record was not used here, it seems well to call attention to the work of Dr. Knox-Shaw at Radcliffe Observatory in the hope that his procedure may be copied by others. The observatory rainfall record was first taken in a roof gage but for many years since then in a more standard exposure. A few years ago the old roof gage was put back into operation in order that the overlapping years may be used to give a homogeneous record. At other stations it probably would be possible to duplicate such work and to improve the records very much.

Before computing the periodogram the writer made an investigation of the permanence of the annual cycle in England and found it subject to large systematic variations. (*1a*) These variations in the type of the annual rainfall are much too large to be accidental and raised the question whether it could be possible for cycles to exist continuously throughout the record. Any cycle existing might plausibly depend upon whatever causes determined the type of the annual rainfall and might cease to exist when the type changed. Many negative results of this paper contribute to this viewpoint and indicate the necessity of further extended study.

The correlation periodogram method need only be outlined very briefly.

Given data x_1, x_2 ---- x_n with x_i representing any datum. Assume the time intervals between x_i and x_{i+1} to be equal. Each datum x_i is matched with the datum l intervals later. l is designated the lag.

$$\text{Compute } r_l \equiv \frac{\Sigma x_i x_{i+l}}{n\sigma_x^2}$$

$$\sigma r_l \equiv \frac{1}{\sqrt{n-l-1}}$$

Values of l are plotted as abscissae and of r_l or of $\frac{r_l}{\sigma r_l}$ as ordinates. The height of the ordinate gives a measure of the probability of a periodicity or cycle of length l.

The periodogram was computed for all values of l from 1 to 352, table 3. This is shown by figure 2.

If long cycles, say 10 years or longer, existed in the data with large amplitude, or if there existed a secular trend to the data, the periodogram should show at first, consistently, large positive ordinates, gradually becoming negative and perhaps again positive. The majority of the first ordinates are positive, but in no case are they large. The writer is forced to the conclusion that the Brückner cycle does not exist in these data. There are successions of dry years and of wet years but the time variation of the swings is too great to give them the term cycle.

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In the correlation periodogram a peak is repeated at l, $2l$, $3l$, etc. if a periodicity of length l exists in the data. Therefore if several periodicities exist, there must be unusually high peaks wherever we have approximate least common multiples. Conversely, interference may suppress certain peaks. The following are the values from the periodogram for which $\frac{r_l}{\sigma r_l}$ is greater than plus two.

Lag	Ratio	Lag	Ratio
27	+2.07	147	+2.57
37	+2.15	194	+2.06
75	+2.07	282	+2.80
124	+2.10	338	+2.37

Larger negative ratios are found. Such also could have physical significance.

A study of the larger ratios found shows that there are but few more found than one would expect through acci-

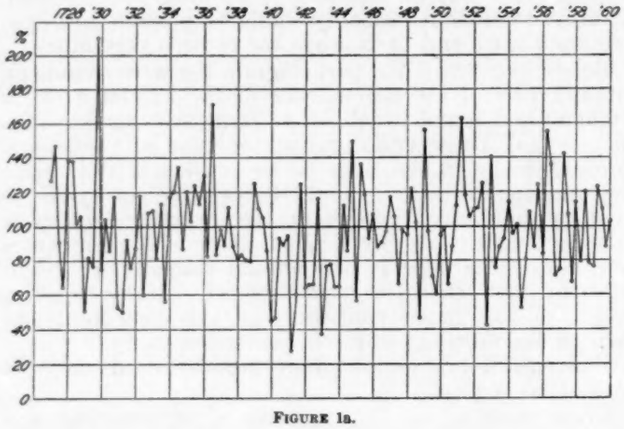

FIGURE 1a.

dent. The increase is scarcely significant. Further evidence will be developed later with respect to the 37–75 peaks, but otherwise the result from this viewpoint must be considered as negative.

There are several possible causes of such negative results:

(*a*) The data may contain no cycles.

(*b*) There may be short cycles which vary in length sufficiently that they will show no peak at a lag of ml if m is a fairly large integer. For example, if there were, say, a half dozen cycles of length between 1 and 3 years and if each varied in legnth by as little as 5 percent of its mean during the 203 years of the data, nothing would be found for long lags and but little for short lags.

(*c*) Short cycles may exist for 25 or 50 years and then become inactive.

(*d*) Short cycles may exist which are subject to abrupt discontinuities of phase such as Professor Turner suggested for sunspots.

The third of these possibilities must be studied further. For perhaps insufficient reasons, the writer does not favor the fourth. The first two hypotheses may be studied together.

If (*b*) should be true, it follows that, if we divide the data to form two independent periodograms, there must, for small lags, be a low positive correlation between them. For great enough lags this correlation must become negative and for still greater lags, haphazard. These correlations can never be large because the majority of the peaks of a periodogram will usually be accidental. The lag for which these correlations become negative is a function of the length of the cycles involved and of their percentage change in length.

The first 192 products of each lag of the periodogram were added separately from the remaining products

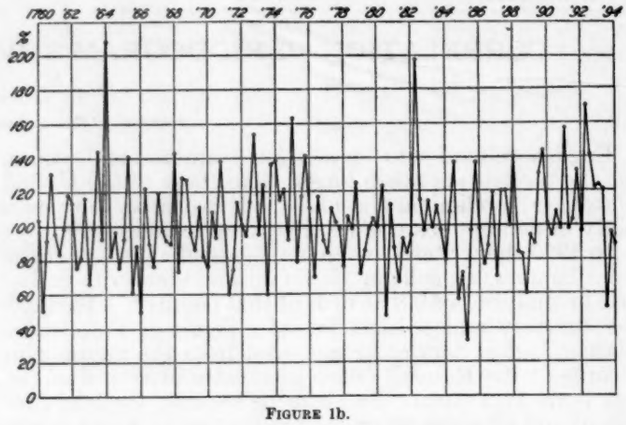

FIGURE 1b.

to give two periodograms, table 3, which are independent, despite some duplication of data. Up to a lag of approximately 150 the correlation between the periodograms is rather consistently positive with the sum of positive products about twice as large as of negative. From here, till near the end, the reverse is true. This evidence strongly favors the existence of a plurality of short cycles. The rather large lag at which the reversal of the correlation takes place indi-

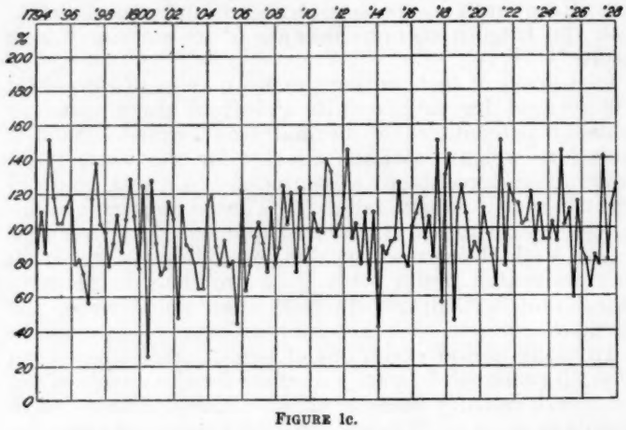

FIGURE 1c.

cates that the percentage variation in length is quite small.

In 1922 the writer published (1*b*) an investigation of rainfall data from many parts of the world which seemed to show quite definitely that there does exist, in numerous places, a rainfall cycle whose phase varies with sunspot phase instead of time and with a length of one ninth the sunspot cycle. The adjustment to sunspot phase by his tables can be carried back only to the year 1860. Monthly values from these data were examined by means of the tables of that paper to study the possibility of existence of this short cycle in them. The values for this cycle for the halves of the

data 1860–1929 are superposed in figure 3. The correlation between them is $r = +0.51$. This value, in con-

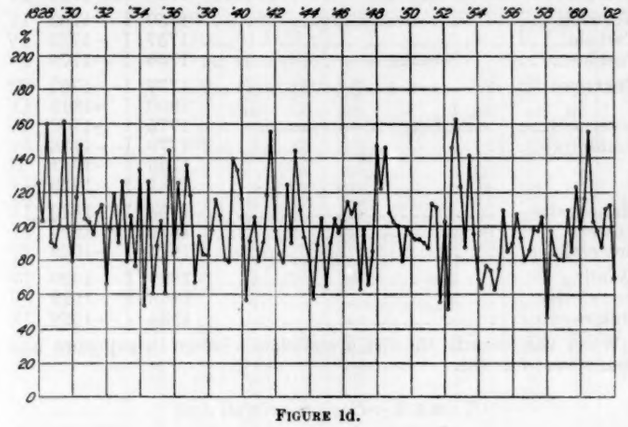

FIGURE 1d.

junction with the evidence of the independent periodograms and that from the 1922 paper, may be regarded as confirming the existence here of this short variable

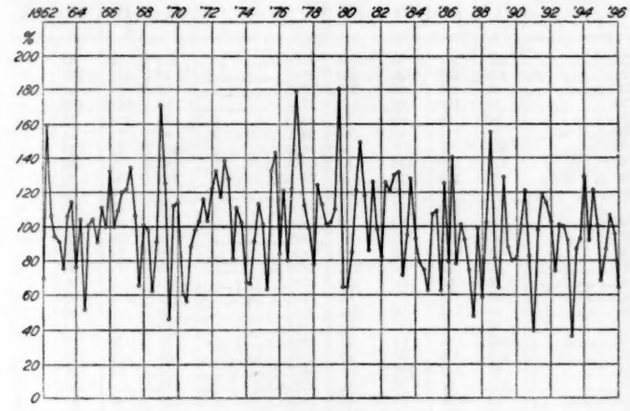

FIGURE 1e.

cycle. The shape of the curve shows that it itself is merely a complex of its harmonies.

When the independent periodograms were examined, it was found that the peak at lag 27 was not consistent

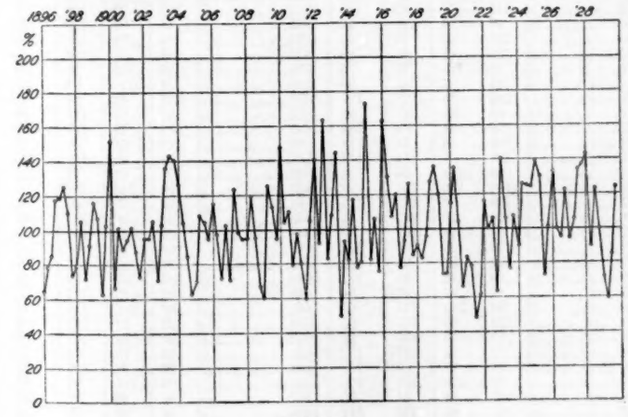

FIGURE 1f.

through the data, and, therefore, is presumably accidental. However, that at 37 and its double at 75 are consistent and warrant further study. For this purpose the 203 years of data were divided into six sections and each tabulated separately for a 37½ quarter cycle. Each of these six curves was then matched to give the best fit

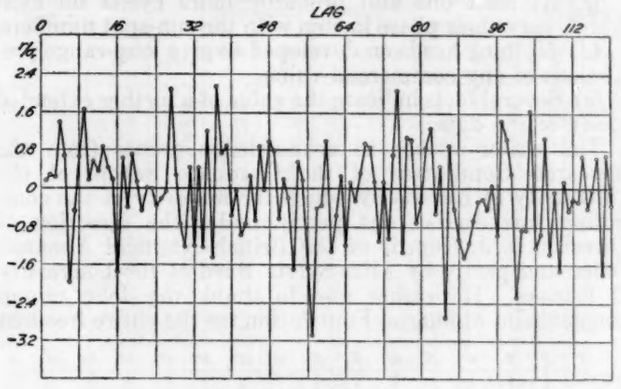

FIGURE 2a.

with the mean of all. The number of quarters by which it was necessary to shift a curve to match it best with the mean curve, gives a measure of its variation in length

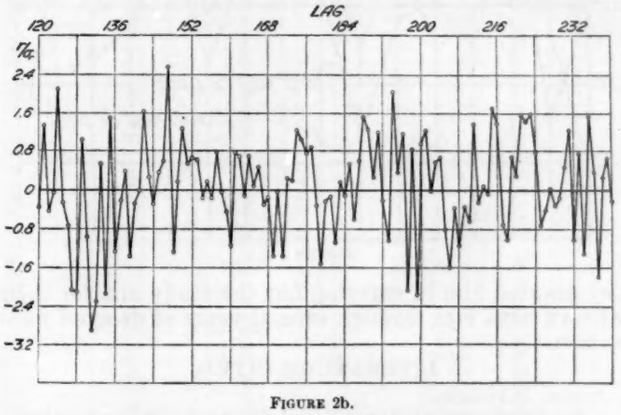

FIGURE 2b.

between these sections of the data if the hypothesis of its real existence be true. These variations expressed as percentages of the mean length are shown in figure 4. On them are superposed the percentage variations for the sun-spot numbers for the same intervals. The resemblance is very strong and, therefore, having admitted the existence

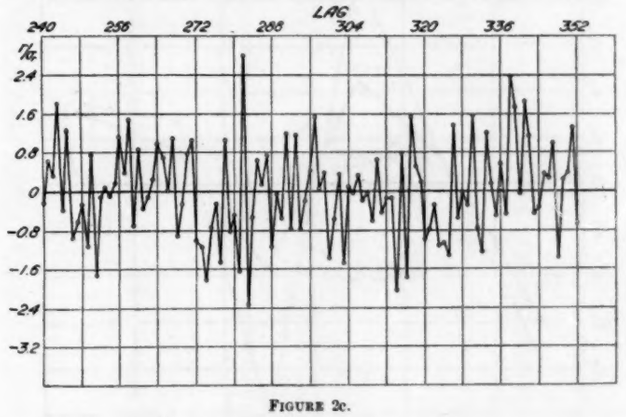

FIGURE 2c.

of one other cycle which varies in a similar manner, this one must be regarded as probably real. It probably is not entirely independent of the shorter one.

SUMMARY OF RESULTS

(*a*) Long cycles do not exist in these data.

(*b*) Strictly periodic terms do not exist.

(*c*) At least one and probably more cycles do exist which vary their phase in step with the sun-spot numbers.

(*d*) Nothing has been developed to give long-range predictions of any commercial value.

(*e*) Several facts indicate the value of a further extended study of the data.

The writer wishes to acknowledge grants from the Research Committee of the Graduate School of the University of Kansas by which the majority of the computing was carried out partly under the direction of Director L. J. Comrie of the British Nautical Almanac Office and partly by Miss Sylvia Burd of the University of Kansas. He wishes also to thank the John Simon Guggenheim Memorial Foundation for the entire freedom

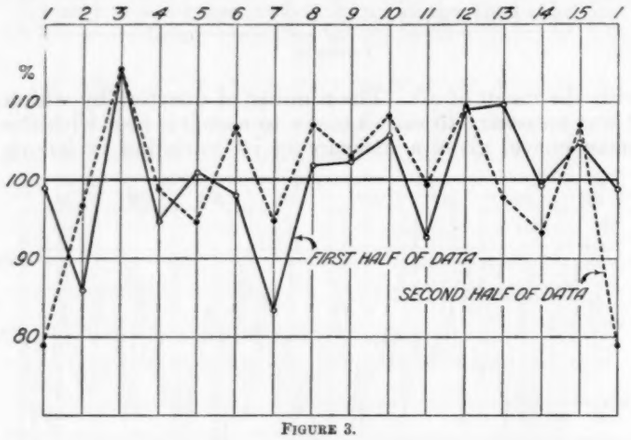

FIGURE 3.

they granted him in carrying out the study and for their patience with him through several years of delayed publication.

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1. ALTER, DINSMORE.
   (*a*) Peculiarity in the variation of distribution of the annual rainfall. Met. Mag. vol. 64, no. 766, November 1929, pp. 234–5.
   (*b*) A rainfall period equal to one ninth the sun-spot period. Kansas University Science Bulletin, vol. XIII, no. 11, July 1922, pp. 17–99.

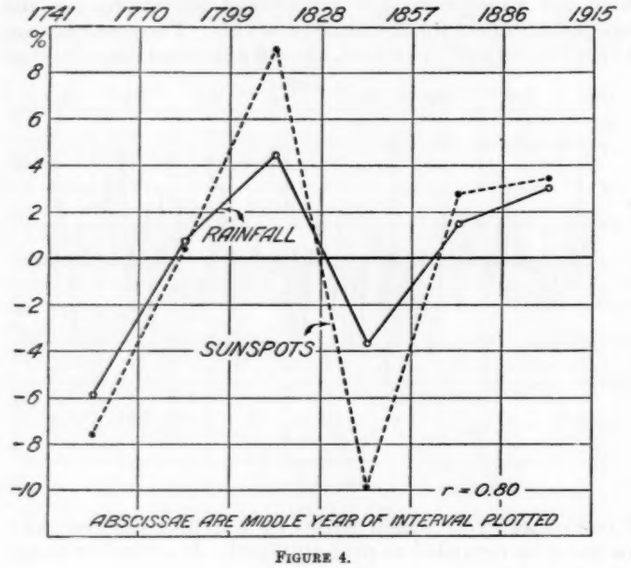

FIGURE 4.

TABLE 1.—*Data used*

Southwick	1727	I	–1739	IV
Plymouth	1727	I	–1752	IV
Lyndon	1736	III	–1798	IV
Norwich	1750	I	–1762	IV
Carlisle	1757	I	–1783	IV
Peebles	1766	I	–1779	IV
Chatsworth	1777	I	–1793	III
	1800	I	–1813	IV
Liverpool	1775	I	–1792	IV
Edinburgh	1770	I	–1776	IV
	1780	I	–1781	II
	1785	I	–1929	IV
Manchester	1794	I	–1840	IV
Exeter	1817	I	–1929	IV
Greenwich	1815	I	–1929	IV
Spalding	1829	I	–1929	IV
Stonyhurst	1848	I	–1929	IV
Chilgrove	1834	I	–1929	IV

When the records showed a sufficient change in exposure new means were formed.

TABLE 2.—*English rainfall data*

[Percentages of normal. First quarter of each year begins with December of preceding year]

	Quarters					Quarters			
	I	II	III	IV		I	II	III	IV
1727	127	147	91	64	1796	119	79	81	73
1728	138	138	102	106	1797	56	117	137	102
1729	50	81	76	210	1798	97	77	91	107
1730	74	104	86	117	1799	86	105	128	107
1731	52	49	92	75	1800	76	124	25	127
1732	87	118	60	108	1801	91	72	76	115
1733	109	81	113	56	1802	105	47	112	90
1734	117	120	134	87	1803	87	79	64	64
1735	120	103	124	113	1804	113	119	89	78
1736	130	82	170	83	1805	93	77	80	44
1737	98	89	111	88	1806	121	63	77	95
1738	81	83	80	79	1807	103	91	74	111
1739	125	110	105	86	1808	79	88	124	102
1740	44	46	93	89	1809	120	74	123	80
1741	94	27	60	124	1810	88	108	98	97
1742	64	65	66	116	1811	139	132	95	102
1743	37	76	77	64	1812	111	145	94	102
1744	64	112	86	149	1813	79	109	69	109
1745	56	136	118	93	1814	42	89	85	92
1746	107	88	91	97	1815	93	126	83	77
1747	117	106	66	98	1816	101	108	117	94
1748	95	122	102	46	1817	106	83	150	56
1749	156	97	70	60	1818	130	142	46	111
1750	95	99	66	88	1819	124	108	82	91
1751	112	162	118	106	1820	86	111	96	84
1752	110	111	125	42	1821	66	150	77	124
1753	140	75	88	93	1822	115	114	102	104
1754	114	96	101	52	1823	120	92	113	93
1755	80	108	88	124	1824	93	103	92	144
1756	84	155	136	71	1825	102	110	59	115
1757	74	142	107	67	1826	87	81	65	84
1758	114	79	120	78	1827	78	141	81	112
1759	76	123	110	88	1828	125	103	160	90
1760	103	51	91	130	1829	88	100	161	99
1761	95	83	98	118	1830	79	117	147	104
1762	113	75	81	116	1831	102	95	108	112
1763	66	98	144	92	1832	65	98	119	90
1764	208	82	96	75	1833	126	79	106	76
1765	92	141	61	88	1834	133	53	126	60
1766	50	122	89	76	1835	88	103	60	144
1767	119	97	91	89	1836	84	125	95	135
1768	143	73	128	127	1837	118	66	94	83
1769	96	86	111	82	1838	82	97	115	106
1770	76	108	93	138	1839	80	78	139	132
1771	100	60	74	114	1840	116	56	91	105
1772	101	94	114	154	1841	79	90	118	155
1773	95	124	60	136	1842	97	83	78	124
1774	138	115	121	92	1843	90	144	109	93
1775	163	79	117	141	1844	79	57	89	104
1776	110	70	117	91	1845	64	90	104	96
1777	84	110	102	98	1846	103	114	107	113
1778	76	105	98	125	1847	62	98	65	85
1779	72	85	98	104	1848	147	122	146	108
1780	99	123	48	112	1849	102	100	79	99
1781	87	67	92	84	1850	95	92	92	90
1782	94	198	115	97	1851	87	113	111	55
1783	114	99	111	97	1852	102	51	146	162
1784	80	108	137	57	1853	123	87	141	95
1785	72	33	97	137	1854	68	63	76	73
1786	98	77	88	119	1855	62	74	109	85
1787	70	120	120	100	1856	90	107	93	80
1788	140	84	83	60	1857	86	98	97	105
1789	94	89	130	144	1858	46	97	83	80
1790	101	94	108	98	1859	80	109	85	123
1791	157	98	103	132	1860	98	116	155	102
1792	96	170	141	122	1861	97	88	110	112
1793	123	121	53	96	1862	69	159	106	94
1794	89	109	86	151	1863	91	75	106	114
1795	118	103	103	112	1864	76	104	51	101

TABLE 2.—*English rainfall data*—Continued

	Quarters					Quarters			
	I	II	III	IV		I	II	III	IV
1865	104	91	111	100	1898	79	105	71	91
1866	132	100	109	120	1899	116	107	62	103
1867	122	134	106	65	1900	151	66	101	89
1868	101	98	62	91	1901	94	101	87	72
1869	170	125	46	112	1902	95	95	105	70
1870	114	61	56	88	1903	103	136	143	140
1871	98	103	116	103	1904	126	104	84	62
1872	122	132	117	138	1905	69	108	104	94
1873	128	81	111	102	1906	115	97	71	112
1874	67	66	91	113	1907	70	123	98	94
1875	101	53	132	143	1908	95	119	95	66
1876	84	121	80	122	1909	60	125	113	94
1877	178	142	112	99	1910	147	104	110	79
1878	77	124	113	101	1911	97	80	59	105
1879	102	110	180	64	1912	140	92	163	83
1880	64	85	121	149	1913	108	144	49	93
1881	118	86	126	98	1914	82	117	77	81
1882	82	126	121	130	1915	172	82	106	75
1883	132	71	95	128	1916	162	130	107	120
1884	93	79	74	62	1917	77	93	126	85
1885	107	109	62	125	1918	90	83	96	127
1886	79	140	78	101	1919	136	120	73	73
1887	92	74	47	99	1920	115	135	104	66
1888	58	102	155	81	1921	83	78	48	61
1889	64	129	88	80	1922	116	100	106	63
1890	82	100	121	83	1923	140	106	76	107
1891	39	98	119	114	1924	90	126	125	124
1892	103	74	101	100	1925	139	130	72	101
1893	92	36	87	93	1926	133	100	95	122
1894	129	92	121	101	1927	94	106	134	137
1895	69	87	107	96	1928	143	90	123	100
1896	64	78	85	118	1929	71	59	85	124
1897	119	125	110	73					

TABLE 3.—*Correlation periodogram of English rainfall*

Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram		Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram	
	r_l	$r_l/\sigma r_l$	Part A	Part B		r_l	$r_l/\sigma r_l$	Part A	Part B
1	+0.005	+0.15	−1.18	+0.83	53	−0.061	−1.69	−1.61	−1.01
2	+.009	+.25	+.80	−.16	54	+.019	+.53	−.32	+.81
3	+.007	+.21	+.77	−.20	55	+.006	+.17	+.45	−.07
4	+.049	+1.37	+2.43	+.21	56	−.061	−1.68	−1.21	−1.23
5	+.025	+.68	+1.72	−.17	57	−.112	−3.09	−2.96	−1.82
6	−.068	−1.94	−.96	−1.68	58	−.016	−.43	+.52	−.80
7	−.017	−.49	+.65	−.93	59	−.014	−.38	+.22	−.57
8	+.0225	+.64	+.70	+.33	60	+.035	+.97	+1.20	+.40
9	+.058	+1.65	+1.33	+1.14	61	−.048	−1.33	−1.97	−.36
10	+.006	+.17	+.05	+.16	62	−.022	−.59	+.93	−1.24
11	+.021	+.57	−.43	+.92	63	+.009	+.24	−.01	+.29
12	+.012	+.35	+.20	+.27	64	−.044	−1.20	−.88	−.87
13	+.030	+.86	+.34	+.80	65	+.004	+.11	−.44	+.39
14	+.015	+.42	+.03	+.46	66	−.010	−.28	+.39	−.55
15	+.006	+.18	−1.14	+.86	67	+.011	+.31	+.76	−.10
16	−.062	−1.73	−1.49	−1.15	68	+.034	+.93	+.77	+.61
17	+.022	+.61	−.52	+1.01	69	+.031	+.84	+.92	+.42
18	−.014	−.41	−.12	−.46	70	+.004	+.12	+.16	+.05
19	+.025	+.70	+.25	+.66	71	−.041	−1.11	−1.13	−.60
20	+.004	+.12	−.82	+.61	72	+.004	+.12	+.64	−.25
21	−.017	−.48	+1.91	−1.64	73	−.039	−1.06	+.96	−1.80
22	.000	+.01	+.47	−.26	74	+.025	+.69	+1.16	+.10
23	−.000	.00	−.88	+.50	75	+.076	+2.07	+2.50	+.88
24	−.014	−.39	−.64	−.08	76	−.049	−1.33	−.69	−1.13
25	−.008	−.22	+1.76	−1.26	77	+.039	+1.06	+1.74	+.18
26	−.003	−.08	−1.45	+.74	78	+.037	+1.00	+.09	+1.10
27	+.074	+2.07	+.65	+2.01	79	−.026	−.70	−.32	−.63
28	+.010	+.28	−.15	+.40	80	−.011	−.30	−1.07	+.30
29	−.027	−.75	−.31	−.68	81	+.030	+.82	+.28	+.78
30	−.044	−1.23	−.15	−1.32	82	+.046	+1.24	−.42	+1.68
31	+.015	+.42	+.79	+.03	83	−.020	−.54	−.96	−.05
32	−.043	−1.20	−1.35	−.59	84	+.017	+.45	+.47	+.24
33	+.015	+.43	+1.58	−.43	85	−.110	−2.71	−2.31	−1.74
34	−.044	−1.23	−.80	−.95	86	+.032	+.87	+1.61	+.04
35	+.043	+1.19	+1.00	+.79	87	−.017	−.45	+.86	−1.04
36	−.051	−1.44	−.71	−1.24	88	−.041	−1.09	−.94	−.70
37	+.077	+2.15	+1.25	+1.73	89	−.053	−1.44	+.34	−1.88
38	+.026	+.73	+1.03	+.24	90	−.043	−1.16	−.64	−.96
39	+.031	+.87	+.96	+.45	91	−.025	−.68	+.43	−1.06
40	−.021	−.59	−.58	−.34	92	−.011	−.30	+.09	−.40
41	−.002	−.06	+.56	−.39	93	−.009	−.25	−.37	−.07
42	−.036	−.99	+.42	−1.38	94	−.017	−.45	+.52	−.84
43	−.027	−.75	+.08	−.90	95	+.002	+.05	+.58	−.29
44	+.009	+.25	+.96	−.26	96	−.037	−1.00	−.75	−.71
45	−.025	−.70	−.03	−.79	97	+.052	+1.40	+.71	+1.20
46	+.029	+.81	+.70	+.52	98	+.038	+1.01	+.03	+1.17
47	−.001	−.02	+.83	−.51	99	+.001	+.03	−.10	+.10
48	+.035	+.96	+.77	+.66	100	−.085	−2.28	−1.15	−1.95
49	+.028	+.79	+.14	+.82	101	−.033	−.38	−.95	−.45
50	−.023	−.65	+.79	−1.20	102	−.036	−.89	−2.27	+.27
51	+.007	+.19	−.22	+.35	103	+.061	+1.63	+1.18	+1.18
52	−.008	−.21	−1.07	+.39	104	−.047	−1.25	+.54	−1.80

TABLE 3.—*Correlation periodogram of English rainfall*—Continued

Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram		Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram	
	r_l	$r_l/\sigma r_l$	Part A	Part B		r_l	$r_l/\sigma r_l$	Part A	Part B
105	−0.036	−0.97	−0.94	+0.56	204	+0.026	+0.65	−1.73	+1.97
106	+.039	+1.03	+.76	+.75	205	−.033	−.80	−1.14	−.18
107	−.052	−1.38	−1.03	−.98	206	−.065	−1.60	−.47	−1.60
108	−.004	−.10	+1.27	−.91	207	−.016	−.39	−.82	−.10
109	−.065	−1.71	−1.07	−1.68	208	−.047	−1.15	−1.22	−.54
110	+.004	+.11	+.41	−.12	209	−.015	−.37	−2.03	+.94
111	−.019	−.49	+.05	−.60	210	−.026	−.65	+.40	−1.05
112	−.009	−.25	−.07	−.25	211	+.055	+1.35	+.21	+1.48
113	−.011	−.30	+.02	−.79	212	−.010	−.25	+.68	−.77
114	+.025	+.67	+.89	+.33	213	+.003	+.08	−1.01	+.79
115	−.016	−.42	−.06	−.45	214	−.004	−.09	+.14	−.20
116	−.001	−.03	−.13	+.05	215	+.070	+1.70	−.06	+2.09
117	+.023	+.60	+.92	+.13	216	+.057	+1.38	+1.77	+.44
118	−.067	−1.78	−2.10	−.77	217	−.030	−.72	−.43	−.58
119	+.026	+.69	−.41	+1.06	218	−.042	−1.03	−1.66	−.10
120	−.014	−.37	−.28	−.26	219	+.028	+.68	+1.19	.00
121	+.050	+1.31	−.39	+1.79	220	+.012	+.30	+1.04	−.37
122	−.016	−.43	−.59	−.14	221	+.064	+1.56	+.89	+1.27
123	−.003	−.07	−1.41	+.81	222	+.058	+1.41	+.56	+1.31
124	+.080	+2.10	+1.21	+1.71	223	+.065	+1.59	+.83	+1.34
125	−.010	−.27	+1.29	−1.13	224	+.032	+.77	+1.40	−.04
126	−.028	−.74	−1.27	−.10	225	−.031	−.76	−.08	−.87
127	−.077	−2.02	−.97	−1.75	226	−.018	−.43	+.92	−1.17
128	−.079	−2.08	−1.48	−1.51	227	.000	+.01	−.28	+.21
129	+.039	+1.02	+.52	+.88	228	−.013	−.32	+.23	−.56
130	−.037	−.98	−2.90	+.69	229	−.008	−.18	+.38	−.49
131	−.111	−2.90	−3.48	−1.00	230	+.019	+.46	−.14	+.66
132	−.009	−.23	−1.74	+.83	231	+.051	+1.22	+1.26	+.60
133	+.020	+.51	+1.04	−.06	232	−.043	−1.03	−1.27	−.36
134	−.046	−1.21	−.97	−.81	233	+.030	+.72	+.86	+.37
135	+.057	+1.50	+.18	+1.65	234	−.054	−1.31	−.45	−1.29
136	−.049	−1.27	−.41	−1.24	235	+.063	+1.51	+.72	+1.32
137	−.009	−.23	+.05	−.30	236	+.015	+.37	−.47	+.78
138	+.015	+.38	+.15	+.36	237	−.074	−1.78	+.02	−2.18
139	−.052	−1.36	−1.16	−.87	238	+.011	+.26	+.53	−.06
140	−.012	−.31	−1.18	+.40	239	+.028	+.67	+1.56	−.30
141	−.001	−.02	+.11	−.10	240	−.009	−.23	+1.42	−1.30
142	+.063	+1.63	+3.42	−.26	241	+.026	+.62	+.85	+.16
143	+.010	+.26	−.45	+.81	242	+.013	+.31	−1.90	+1.75
144	−.012	−.30	+.34	−.55	243	+.076	+1.82	+2.52	+.40
145	+.014	+.35	−.70	+.86	244	−.017	−.40	−.67	−.01
146	+.022	+.58	+.69	+.24	245	+.051	+1.22	+.92	+.83
147	+.100	+2.57	+2.96	+1.15	246	−.041	−.97	−1.53	−.08
148	−.049	−1.27	−.184	−.31	247	−.028	−.63	+.64	−1.27
149	+.006	+.16	−.83	+.72	248	−.012	−.28	+.10	−.41
150	+.049	+1.26	+.40	+1.25	249	−.047	−1.12	+.41	−1.67
151	+.020	+.52	−.44	+.90	250	+.031	+.73	+1.27	+.05
152	+.025	+.64	+1.41	−.31	251	−.072	−1.70	−.17	−1.95
153	+.024	+.61	+1.03	+.05	252	−.006	−.13	+.84	−.77
154	−.007	−.17	+.75	−.69	253	.000	+.07	+1.43	−1.03
155	+.006	+.16	+.40	−.08	254	−.004	−.10	−.62	+.33
156	−.007	−.18	+.96	−.84	255	+.006	+.15	+1.09	−.62
157	+.030	+.77	+.24	+.76	256	+.047	+1.10	+.17	+1.23
158	−.002	−.05	−1.37	+.83	257	+.016	+.38	+2.06	−1.04
159	−.018	−.46	+.20	−.68	258	+.062	+1.45	+1.17	+.93
160	−.044	−1.13	−.13	−1.25	259	−.030	−.71	−2.00	+.60
161	+.030	+.77	+.33	+.69	260	+.036	+.84	+2.52	−.82
162	+.027	+.68	+.01	+.81	261	−.016	−.38	+1.74	−1.77
163	−.005	−.13	+.21	−.29	262	−.005	−.12	+.79	−.75
164	+.027	+.69	+.37	+.40	263	+.009	+.22	+.43	−.05
165	+.003	+.06	−.76	+.66	264	+.041	+.95	+1.12	+.35
166	+.018	+.45	+.14	+.44	265	+.029	+.69	+.26	+.67
167	−.012	−.31	−1.63	+.69	266	+.001	+.01	−.52	+.40
168	−.008	−.19	−.28	−.04	267	+.046	+1.08	+1.75	+.04
169	−.055	−1.38	−.91	−1.03	268	−.040	−.93	−1.35	−.15
170	−.002	−.04	−.25	+.11	269	−.011	−.27	−.35	−.07
171	−.054	−1.37	−.14	−1.55	270	+.033	+.77	+.19	+.82
172	+.009	+.22	−.55	+.63	271	+.043	+1.01	+2.09	−.31
173	+.008	+.19	+.92	−.38	272	−.047	−1.09	−.45	−1.02
174	+.048	+1.21	+.58	+1.06	273	−.050	−1.50	−2.20	−.21
175	+.040	+1.02	+.57	+.83	274	−.078	−1.81	−1.39	−1.21
176	+.030	+.74	−1.31	+1.76	275	−.032	−.75	−.10	−.87
177	+.034	+.87	+.86	+.46	276	−.012	−.27	+1.50	−1.47
178	−.013	−.34	−.39	−.15	277	−.068	−1.56	−1.46	−.87
179	−.061	−1.53	−.32	−1.61	278	+.044	+1.01	+.35	+1.01
180	−.009	−.24	−.13	−.20	279	−.035	−.81	−1.68	+.25
181	−.006	−.16	+.61	−.60	280	−.022	−.50	+1.40	−1.09
182	−.044	−1.10	−1.01	−.65	281	−.071	−1.64	−3.23	+.42
183	+.006	+.15	+1.45	−.78	282	+.126	+2.80	+1.33	+2.60
184	−.005	−.12	−1.44	+.79	283	−.101	−2.32	−2.43	−1.04
185	+.021	+.53	+.88	+.05	284	+.024	+.55	+1.66	−.59
186	−.025	−.62	−.64	−.32	285	−.008	−.18	−.03	−.21
187	+.024	+.60	+1.18	−.08	286	−.030	−.68	−.90	−.17
188	+.060	+1.51	+.66	+1.37	287	−.004	−.08	+.34	−.36
189	+.050	+1.25	+.11	+1.42	288	−.050	−1.14	+.73	−1.98
190	+.010	+.24	+.66	−.15	289	−.003	−.08	+1.92	−1.57
191	+.048	+1.19	+.67	+.98	290	−.025	−.57	−1.62	+.83
192	−.009	−.23	+1.29	−1.15	291	+.052	+1.18	+1.95	−.03
193	−.042	−1.05	−.99	−.60	292	−.034	−.77	+.40	−1.27
194	+.083	+2.06	+.99	+1.80	293	+.041	+.93	+.29	+.95
195	+.015	+.36	−.69	−.90	294	−.034	−.77	+.11	−1.07
196	+.047	+1.16	−.54	+1.69	295	−.009	−.21	−.20	−.10
197	−.084	−2.07	−2.23	−.98	296	+.018	+.41	−.46	−.87
198	+.036	+.90	+.45	+.77	297	+.067	+1.52	+.61	+1.43
199	−.087	−2.15	−2.86	−.65	298	+.002	+.05	+1.59	−1.17
200	+.039	+.95	−1.08	+1.89	299	+.017	+.38	+.76	−.12
201	+.050	+1.22	+.69	+1.00	300	−.060	−1.37	−1.96	−.19
202	−.001	−.02	+.45	−.33	301	−.026	−.59	−.43	−.41
203	+.023	+.57	−2.18	+2.19	302	+.014	+.33	+.68	−.12

TABLE 3.—*Correlation periodogram of English rainfall*—Continued

Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram	
	r_l	$r_l/\sigma r_l$	Part A	Part B
303	−0.066	−1.48	+0.39	−2.18
304	+.004	+.08	+.77	−.56
305	−.002	−.03	−.28	+.18
306	+.014	+.31	+.67	−.14
307	−.009	−.20	−.69	+.29
308	−.001	−.03	−.19	+.12
309	−.027	−.60	+.66	−1.28
310	+.028	+.63	−.95	+1.56
311	−.020	−.45	+.28	−.80
312	−.008	−.17	−.81	+.43
313	−.007	−.15	+.34	−.47
314	−.090	−2.01	−1.72	−1.18
315	+.035	+.78	+1.21	+.02
316	−0.080	−1.78	−1.58	−0.98
317	+.099	+1.53	+.46	+1.58
318	+.022	+.50	+.42	+.30
319	+.009	+.19	−1.26	+1.26
320	−.045	−1.00	−.23	−1.11
321	−.036	−.80	−.63	−.50
322	−.013	−.30	+.80	−1.02
323	−.051	−1.12	−1.82	+.04
324	−.049	−1.08	−.92	−.63
325	−.059	−1.31	−1.31	−.60
326	+.061	+1.34	+.51	+1.30
327	−.025	−.55	−1.54	+.55
328	−.001	−.15	−.70	+.55

TABLE 3.—*Correlation periodogram of English rainfall*—Continued

Lags	Entire periodogram		$r_l/\sigma r_l$ of independent parts of periodogram	
	r_l	$r_l/\sigma r_l$	Part A	Part B
329	−0.014	−0.30	+0.36	−0.67
330	+.071	+1.55	+1.38	+.87
331	−.035	−.76	+.07	−1.03
332	−.057	−1.25	−.90	−.88
333	+.054	+1.19	+.73	+.93
334	+.007	+.15	−1.24	+1.21
335	−.023	−.50	+.32	−.91
336	+.025	+.55	+1.20	−.37
337	−.022	−.48	−1.05	+.25
338	+.109	+2.37	+1.41	+1.90
339	+.080	+1.74	+.48	+1.88
340	−.002	−.04	−.98	+.77
341	+0.086	+1.86	+0.98	+1.52
342	+.042	+.91	+.60	+.68
343	−.022	−.47	−.60	−.12
344	−.016	−.34	−1.21	+.58
345	+.016	+.34	−.21	+.62
346	+.012	+.26	−1.23	+1.38
347	+.045	+.98	+.77	+.74
348	−.063	−1.36	−2.07	−.02
349	+.011	+.23	+.20	+.13
350	+.018	+.39	+.31	+.24
351	+.061	+1.30	+.39	+1.37
352	−.032	−.69	−1.86	+.70

SIGNIFICANT CHANGES IN THE RAINFALL AT SOME LOCALITIES

By DEAN A. PACK

INTRODUCTION

These data are presented to support the generally prevalent, though many times questioned, belief in weather recurrences and weather cycles. No attempt has been made to establish any direct or indirect relation between precipitation and sun-spot cycles or any other kind of periodic variation. However, an effort has been made to show that precipitation cycles do exist, and that the precipitation for many different localities show significant changes from period to period.

SUMMARY

These points have been supported by the calculation of cycles for several precipitation records, and by showing that the differences in the amount of rainfall during the maximum and during the minimum periods for these records could not be due to chance alone.

A cycle or trend for each precipitation record was calculated and the curve plotted, so that the periods of high or low average rainfall could be located. This was done for the annual precipitation records of 41 stations in the United States and 12 stations in other parts of the world. The crests and troughs of these curves indicated periods of maximum or high average and periods of minimum or low average rainfall for each station, respectively. The annual precipitation during the periods of maximum rain fall were compared statistically with the annual precipitation during the periods of minimum rainfall for each station. The results show that the precipitation for each station passes through a particular cycle during which time it varies by significant amounts. As a result there are significant maximum and minimum periods.

The annual precipitation during successive maxima periods and minima periods were also statistically compared. No significant difference of average annual precipitation was found between successive maxima periods or between successive minima periods for any particular station. While this indicates that successive cycles may have about the same amplitude, no definite conclusion is possible because our weather records are too short.

HISTORICAL

Sir Richard Gregory's (**6**) address before the Royal Meteorological Society will be found of interest as a review of the present opinion on weather cycles and of the more recent literature. In 1915 Goodnough (**3**) pointed out that the rainfall for various localities in New England changed from time to time. In 1930 he (**4**) presented the following table 1 which is self-explanatory and which is reprinted here by permission of the New England Water Works Association.

TABLE 1.—*Average annual rainfall by periods (inches)*

Period	New Bedford, Mass.	Boston, Mass.	Waltham, Mass.	Lowell, Mass.
1826–49, 24 years	47.21	42.00	41.13	39.45
1850–76, 27 years	46.73	53.18	43.00	45.73
1877–1903, 27 years	47.79	45.52	44.40	45.95
1904–29, 26 years	44.23	40.32	40.24	41.43
1826–1929, 104 years	46.49	45.40	42.24	43.26

Marvin (**7**) in an article entitled "Concerning Normals, Secular Trends and Climatic Changes" discussed the precipitation changes for Boston vicinity from 1758 on. Powell (**8**) presented a method for finding long period cycles and showed that a cosine curve fits the Boston precipitation data much closer than straight line trends.

SOURCES OF MATERIAL

The data used for these calculations were taken from the records of the United States Weather Bureau, the New England Water Works Association, the Smithsonian Institution (**1**), and the Meteorological Service of Canada.

INVESTIGATION

The Goutereau (**5**) Ratio was applied to several annual precipitation records, with a result that the data indicated the presence of a cycle.

In order to select periods from the annual precipitation records that had a high or low average annual precipitation, cycles were calculated and curves drawn for the precipitation record of each station. These cycles were calculated by the least squares method or by moving averages. The least square method was used only on parts of long records that could be represented by more simple curves. From these curves, it was an easy matter to select from the records periods having either a high or a low average annual precipitation.

An idea of the fit of the curves used in this work may be had by comparing the curve for the annual precipitation of Boston with Powell's (8) long period cycle for Boston calculated by a method of successive integration.

Boston precipitation

	Powell	Author
Period for data used	1818–1928	1818–1931
Normal	44.34	44.30
Date of recent minimum	1911	1910½
Date of earlier minimum	1815	
Date of recent maximum	1865	1865
Average deviation from cycle	4.28	4.23

While some of the curves may not be exact and represent the best fit, it is believed that any one of them fits the data more accurately than would a straight line.

After the curves were drawn samples were taken from the annual precipitation records of each locality and compared statistically to determine whether or not the amount of rainfall had changed from time to time. One sample representing maximum rainfall and one sample representing minimum rainfall were taken from each annual precipitation record at the points indicated by the crest and the trough of the curve, respectively. Each sample consisted of the recorded annual precipitation for the particular locality during a period of 10 or 30 consecutive years. In order to avoid any effect that might be due to the natural *order of succession* (**10**), the order of the annual precipitation values for each one of all samples was determined by chance and so arranged before the statistical analysis was commenced. After the annual precipitation values or raw data in both maximum and minimum samples for any locality were arranged by chance, the samples were analyzed to determine if they were significantly different or not. The method used for calculating these results which are given in table 2 was that given by Fisher (**2**) under section 24, pages 104–107. If there was any question as to the value of P obtained by this method it was checked by the method he gives in section 24.1, pages 107–111.

TABLE 2.—*Probability that the difference found between the maximum and minimum rainfall for 10- and 30-year periods might be due to chance only*

No.	Locality	Part of record from which samples were selected		Mean annual precipitation during the periods of—		Probability, *P*
		Maximum	Minimum	Maximum	Minimum	
				Inches	*Inches*	
1	Albany, N.Y.	1867–76	1905–14	42.96	29.84	0.01
2	Amherst, Mass.	1895–1904	1905–14	47.60	39.68	.01
3	Austin, Tex.	1873–82	1889–98	53.43	36.15	.01
4	Boise, Idaho	1869–78	1920–29	15.53	11.80	.06
5	Boston, Mass.	1861–70	1905–14	57.25	35.22	.01
5a	do	1851–80	1896–25	51.95	38.55	.01
6	Burlington, Vt.	1860–69	1907–16	36.48	28.35	.01
7	Cambridge, Mass.	1854–63	1909–18	51.98	37.61	.01
8	Charleston, S.C.	1864–93	1896–1925	55.68	41.05	.01
9	Chicago, Ill.	1876–85	1910–19	39.78	30.49	.01
10	Cincinnati, Ohio	1875–84	1894–1903	46.87	32.57	.01
11	Concord, N.H.	1884–93	1908–17	40.04	32.98	.01
12	Cornish, Maine	1893–1902	1874–83	52.50	42.06	.01
13	Denver, Colo.	1906–15	1893–1902	16.29	12.70	0.04
14	Gardner, Maine	1850–59	1905–14	48.28	38.62	.01
15	Hartford, Conn.	1888–97	1909–18	49.76	39.27	.01
16	Lakeport, N.H.	1884–93	1905–14	45.64	37.12	.01
17	Key West, Fla.	1878–97	1890–99	42.50	34.62	.21
18	Lowell, Mass.	1881–90	1837–46	42.76	36.65	.01
19	Marietta, Ohio	1859–68	1836–45	44.75	38.57	.20
20	Middletown, Conn.	1894–1903	1910–19	51.91	41.26	.01
21	New Bedford, Mass.	1868–77	1909–18	48.93	41.45	.02
22	New Haven, Conn.	1873–82	1891–1900	52.14	42.30	.01
23	New Orleans, La.	1871–80	1890–99	65.47	46.99	.01
24	New York, N.Y.	1884–93	1834–43	48.81	35.56	.01
24	Omaha, Nebr.	1875–84	1910–19	39.22	23.75	.01
26	Philadelphia, Pa.	1865–74	1877–86	50.44	36.70	.01
27	Portland, Maine	1884–93	1905–14	47.23	37.36	.01
28	Portland, Oreg.	1874–83	1916–25	56.70	38.20	.01
29	Providence, R.I.	1868–77	1832–41	49.53	37.96	.01
30	Sacramento, Calif.	1860–69	1916–25	19.60	13.77	.01
31	St. Paul, Minn.	1865–74	1923–32	32.19	24.09	.01
32	Salt Lake City, Utah	1906–15	1887–96	17.45	14.71	.01
33	San Diego, Calif.	1877–86	1892–1901	12.24	7.69	.05
34	San Francisco, Calif.	1880–89	1897–1906	25.06	18.88	.07
35	Santa Fe, N.Mex.	1874–83	1917–26	15.64	13.22	.23
36	Springfield, Mass.	1884–93	1909–18	49.00	37.61	.01
37	St. Louis, Mo.	1846–55	1894–1903	47.54	34.67	.01
38	Waltham, Mass.	1884–93	1837–46	47.53	39.08	.01
39	Washington, D.C.	1882–91	1921–30	48.15	38.40	.04
40	Winnemucca, Nev.	1878–97	1910–19	10.00	8.02	.11
41	Yuma, Ariz.	1905–14	1875–84	4.86	2.66	.12
	FOREIGN STATIONS					
42	Berlin, Germany	1860–69	1911–20	6.22	5.32	.02
43	Calcutta, India	1862–71	1889–98	72.60	55.58	.04
44	Cape Town, South Africa	1883–92	1864–73	30.37	23.33	.01
45	Copenhagen, Denmark	1824–33	1881–90	6.36	5.20	.04
46	Greenwich, England	1872–81	1893–1902	68.18	54.46	.01
47	Honolulu, T.H.	1895–1904	1905–14	38.23	22.22	.01
48	Madras, India	1839–48	1828–37	57.58	38.16	.01
49	Rome, Italy	1898–1907	1832–41	1,020.6	641.5	.01
50	Sidney, New South Wales	1870–79	1901–10	55.54	39.10	.01
51	St. Johns, Canada	1890–99	1878–87	59.47	51.40	.03
52	Stykkisholm, Iceland	1896–1905	1877–86	719.7	550.7	.01
53	Toronto, Canada	1861–70	1879–88	35.08	29.97	.01

The limit of the probability *P* for significance in this type of analyses has been placed at 0.05. Therefore, the items with a probability of less than this indicate that the maximum and minimum samples as listed in table 2 and analyzed were found significantly different and that one would not expect to find such differences as due to chance only. The results also show that these stations have maximum periods of 10 years or more in length during which time the rainfall is significantly greater than during the corresponding lengthened minimum period.

The phase of the cycles for some of the stations, as for example Boston, Mass., and Charleston, S.C., were so long that it was possible to select periods of 30 or more years in length having significant maximum and minimum rainfall characteristics.

The probability values for the stations nos. 4, 17, 19, 33, 34, 35, 40, and 41 are large and show that the 10-year maximum periods of rainfall were not significantly different from the minimum periods of rainfall. It was noted that these stations had shorter cycles and the length of the samples were accordingly reduced to 5 years. Table 3 gives the probability values for the significance of the difference between the maximum and minimum 5-year samples taken from these same station records.

TABLE 3.—*The probability that the differences found between the maximum and minimum rainfall for periods of 5 years might be due to chance*

No.	Locality	Part of record from which samples were taken		Mean annual precipitation during periods of—		P
		Maximum	Minimum	Maximum	Minimum	
				Inches	*Inches*	
4	Boise, Idaho	1869–73	1886–70	18.51	11.63	0.02
17	Key West, Fla	1851–55	1859–63	47.03	32.16	.01
19	Marietta, Ohio	1865–69	1891–95	47.15	34.63	.02
33	San Diego, Calif	1886–90	1896–1900	12.28	6.84	.02
34	San Francisco, Calif	1864–68	1897–1901	28.55	20.63	.04
35	Santa Fe, N.Mex	1874–78	1888–92	17.33	12.24	.01
40	Winnemucca, Nev	1883–87	1901–5	9.41	7.22	.04
41	Yuma, Ariz	1905–9	1899–1903	6.80	1.60	.01

While the records for these stations have significant 5-year maximum and minimum rainfall periods, the differences are not so great as found elsewhere.

The differences between the maximum and minimum rainfall for some stations were calculated by Bessel's formula. The mean annual precipitation for Boston from 1851 to 1880 was 51.95 ± 0.91 inches, while that for the minimum period from 1818 to 1847 was 41.07 ± 0.77 inches. The difference between these means is 10.89 ± 1.19 inches or about 25 percent of the recorded mean annual precipitation (41.02 to 1931) for Boston. This mean difference is statistically significant and shows that Boston had significantly more rainfall from 1851 to 1880 than during the earlier period. Another example will also illustrate this point. The mean annual precipitation for Charleston, S.C., from 1864 to 1886 was 56.81 ± 1.68 inches, while that for the period 1841 to 1863 was only 42.70 ± 1.13 inches. The difference between these means is 14.11 ± 1.34 inches and shows a significant difference between the maximum and minimum rainfall periods of Charleston. As significantly different maximum and minimum rainfall periods have occurred in the annual precipitation records of all these stations, it naturally follows that the average annual rainfall (precipitation) at these stations has changed from time to time.

Successive maxima and successive minima periods of rainfall for some of these stations have been compared. The annual precipitation record for Charleston, S.C., extends over two periods of minimum rainfall. The calculated cycle showed these minima to be at 1852½ and 1906. A comparison of the annual precipitation from 1848 to 1857 with that from 1902 to 1911 gave a probability value of 0.70. This indicated that the samples were alike and that one could expect to find similar differences due to chance only. Similar comparisons of the Lowell minima at 1840 and 1913, New Bedford maxima at 1828 and 1893, New Bedford minima at 1841 and 1913, New York City minima at 1838 and 1916, and Waltham minima at 1840 and 1920 gave probability values of 0.22, 0.69, 0.29, 0.25, and 0.81, respectively. All these values are well over 0.05 and indications are that these successive maxima are essentially equal and that these successive minima are also nearly equal.

Acknowledgments are due X. H. Goodnough, G. A. Loveland, and other meteorologists located at each of the represented stations for kindly furnishing most of the data used in these calculations, also R. W. Powell and C. F. Brooks for offering constructive criticism.

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A COMPARISON OF DROUGHT CONDITIONS IN GEORGIA AND ARKANSAS

By GEORGE W. MINDLING
[Weather Bureau office, Atlanta, Ga., Jan. 10, 1934]

A study of droughts in Georgia was recently completed following the methods applied by H. S. Cole in his article on Droughts in Arkansas, published in the MONTHLY WEATHER REVIEW for May 1933. It was desired to bring to light what the records show as to frequency of dry spells in Georgia and to compare such frequency with that in Arkansas as well as to examine such other drought conditions as might seem to be of interest.

Mr. Cole used the period of 1898–1930, inclusive, but in Georgia not many original records were found available for years prior to 1900. Therefore, it seemed best to use the period of 1900–1932 partly because the record of a station could be followed more easily in the original records than in the tables of daily precipitation published in monthly reports and partly because by beginning with 1900 it was possible to select 12 well-distributed stations having unbroken records through a 33-year period.

The inherent difficulties in defining drought in terms of rainfall are so generally realized and have been discussed by so many writers that it seems needless now to add to what has already been said on the subject. While no entirely satisfactory definition of drought has been formulated in terms of rainfall, still it is possible to make a valuable comparison of the drought conditions in one State with those of another by applying the same criteria and methods of analysis to the long-period records of a sufficient number of stations in each region.

The tables accompanying this paper present a summary of the results obtained in Arkansas and Georgia. The data for Arkansas have been taken from the published article by Mr. Cole cited above, while those for Georgia were derived by applying the same methods employed by Mr. Cole in his State. It is believed that this comparison may be regarded as a very satisfactory one, since 12 well-distributed stations were used in each State and the period covered by the records was of the same length and nearly identical as to the years included.

Mr. Cole says:

> It was decided to use all 15-day periods without measurable rainfall during the warmer months, May to September, inclusive,

and to use 20-day periods without measurable precipitation during the remainder of the year. It was also decided that periods of over 15 days during the warmer months should be included if the rainfall for the additional days was at a rate less than 1 inch for each additional 15 days, and during the remainder of the year dry periods of over 20 days should be included if the precipitation for the additional days was at a rate less than 1 inch for each additional 30 days.

Under these restrictions Mr. Cole found for Arkansas a total of 844 droughts of various lengths from 15 to 126 days in the records of 12 stations within the 33-year period 1898–1930. This is slightly more than 2 droughts per year on the average at a given station, since the total amount of record compiled corresponds to 12 times 33, or 396 years for a single station. In Georgia the total number of droughts came out 770 for 12 stations during a period of 33 years, which is slightly less than 2 droughts per year on the average for a given station. This indicates a noticeable, though not important, difference between the two States, so far as mere frequency of droughts is concerned.

When the season of occurrence of the droughts is taken into consideration there is seen to be an important difference in favor of Georgia. Doubtless the droughts beginning in June, July, and August will in the long run result in more harm than those beginning in any other 3-month period. Georgia's droughts beginning in these months number only 191 as compared with 368 in Arkansas. This is seen to be quite significant when we consider how much less harmful the dry spells of other seasons generally are. A shortage of rainfall during the spring season, unless very acute, will be favorable for planting and cause little harm. Likewise a moderate shortage in the fall favors seeding operations and cotton harvesting.

Winter droughts in Georgia, as shown in table 1, are less frequent than those of any other season and are seldom of more than 30 days' duration.

While the total number of droughts is appreciably less in Georgia than in Arkansas, especially as to those that occur during the most important growing months, Georgia (see tables 2 and 3) has the larger number of the more prolonged droughts, especially of those that continue from 30 to 69 days. Out of 770 droughts in Georgia, 367, or nearly 48 percent, lasted 30 days or more, while Arkansas had 275 such droughts out of 844, or about 32 percent.

At individual stations in Georgia the total number of droughts within the stated 33 years ranged from 42 at Dahlonega in the northern section to 82 at Macon near the center of the State. The region of greatest drought frequency in Georgia is definitely indicated to be in the central and eastern counties northward about three fourths of the way over the State, with a rapid falling off beyond this area both to the west and north. As would naturally be expected, the region of least drought frequency is in the northern mountainous area where the normal rainfall is greatest.

In Arkansas the relative frequency appears to be greatest across the southern counties and least in the extreme northeast section, ranging from 93 at Arkansas City to 50 at Pocahontas. However, there is a somewhat surprising irregularity of distribution in the central part of the State. The total number of droughts found for Dardanelle somewhat northwest of the center of the State is 91, while the totals for the nearest surrounding stations used, beginning to the west and going clockwise around on the map are, respectively: Fort Smith, 66; Rogers, 63; Calico Rock, 75; Newport, 68; Little Rock, 58; and Mena, 65.

TABLE 1.—*Dry periods in 33 years, by months, for 12 stations in Georgia. Totals are shown for both Georgia and Arkansas*

Duration in days	January	February	March	April	May	June	July	August	September	October	November	December	Year
15 to 19	0	0	0	3	27	16	12	18	31	0	0	0	107
20 to 29	24	12	14	33	19	25	8	39	46	54	11	11	296
30 to 39	7	0	5	28	22	5	3	26	19	23	8	3	149
40 to 49	0	6	6	18	7	1	0	13	15	16	5	4	91
50 to 59	0	2	5	14	0	0	0	6	14	12	0	0	53
60 to 69	0	0	3	1	1	0	1	8	13	4	0	0	31
70 to 79	1	0	2	1	0	0	2	0	4	2	0	1	13
80 to 89	3	0	1	2	0	0	0	3	1	0	1	1	12
90 to 99	0	1	2	0	0	0	0	1	3	2	1	0	10
100 or more	0	0	0	0	1	0	0	4	1	2	0	0	8
Totals in Georgia	35	21	38	100	77	47	26	118	147	115	26	20	770
Totals in Arkansas	32	15	22	19	96	106	103	159	125	96	27	44	844

TABLE 2.—*Dry periods at 12 stations in Georgia in 33 years. Corresponding totals are shown for both Georgia and Arkansas*

Stations	15 to 19 days	20 to 29 days	30 to 39 days	40 to 49 days	50 to 59 days	60 to 69 days	70 to 79 days	80 to 89 days	90 to 99 days	100 or more days	Greatest number of days in any drought	Precipitation in the longest drought
Albany	9	22	12	5	1	4	2	0	1	1	104	2.83
Athens	15	26	13	7	3	0	0	0	0	1	134	2.97
Columbus	4	18	16	8	2	6	0	1	0	1	104	2.86
Dahlonega	9	19	5	4	2	2	1	0	0	0	71	.80
Dublin	9	29	14	7	5	0	0	1	4	1	103	2.07
Macon	5	26	12	18	9	4	4	2	2	0	99	2.38
Newnan	13	24	16	7	5	2	0	1	0	0	87	1.27
Rome	8	22	8	8	6	1	0	1	0	0	86	2.62
Savannah	6	26	12	7	8	3	2	3	3	3	135	3.24
Thomasville	6	18	10	8	4	4	2	0	0	0	78	.51
Washington	14	33	20	3	2	2	1	1	0	0	80	1.85
Waycross	9	33	11	9	6	3	1	2	0	1	144	2.59
Totals in Georgia	107	296	149	91	53	31	13	12	10	8	------	------
Totals in Arkansas	204	365	121	52	39	16	20	12	5	10	------	------

TABLE 3.—*Number of dry periods in Georgia (12 stations during 33 years) with 15 days or more, 20 days or more, etc. Corresponding totals are shown for both Georgia and Arkansas*

Stations	15 days or more	20 days or more	30 days or more	40 days or more	50 days or more	60 days or more	70 days or more	80 days or more	90 days or more	100 days or more
Albany	57	48	26	14	9	8	4	2	2	1
Athens	65	50	24	11	4	1	1	1	1	1
Columbus	56	52	34	18	10	8	2	2	1	1
Dahlonega	42	33	14	9	5	3	1	0	0	0
Dublin	70	61	32	18	11	6	6	6	5	1
Macon	82	77	51	39	21	12	8	4	2	0
Newnan	68	55	31	15	8	3	1	1	0	0
Rome	54	46	24	16	8	2	1	1	0	0
Savannah	73	67	41	29	22	14	11	9	6	3
Thomasville	52	46	28	18	10	6	2	0	0	0
Washington	76	62	29	9	6	4	2	1	0	0
Waycross	75	66	33	22	13	7	4	3	1	1
Totals in Georgia	770	663	367	218	127	74	43	30	18	8
Totals in Arkansas	844	640	275	154	102	63	47	27	15	10

A STUDY OF THE VARIATION IN ANNUAL RAINFALL OF OAHU ISLAND (HAWAIIAN ISLANDS) BASED ON THE LAW OF PROBABILITIES

By WINTERS T. NAKAMURA

[Weather Bureau office, Honolulu, Hawaii, December 1933]

SYNOPSIS

By a method explained in detail the probabilities of the occurrences of extreme rainfalls were computed for a number of stations on Oahu. These values are given in table 3. The coefficients of variation were determined for 42 stations and plotted in figure 10. The significance of this map is discussed in the latter part of the paper.

Since the Hawaiian Islands are very mountainous and in a trade-wind region it follows, for reasons well known, that the annual amount of precipitation over them varies greatly from place to place. This is well shown by a study of the average annual rainfall of Oahu made by J. F. Voorhees (1). Figure 1 is an average annual rainfall map of Oahu Island, taken from that study, which shows the wide divergences that obtain in the average rainfall over short distances, the relative importance of elevation and distance from crest in determining isohyetal lines, and, in general, a good, broad view of the quantitative rainfall of the island. However, it does not show the variations that are known to occur at many places from year to year, and which for problems of water supply and flooding of streams, extreme conditions and fluctuations are perhaps of greater importance than average conditions. This study was undertaken to supplement Voorhees' paper with that additional useful information.

The variation in annual rainfall at Honolulu (U.S. Weather Bureau Office) is shown graphically in figure 2.

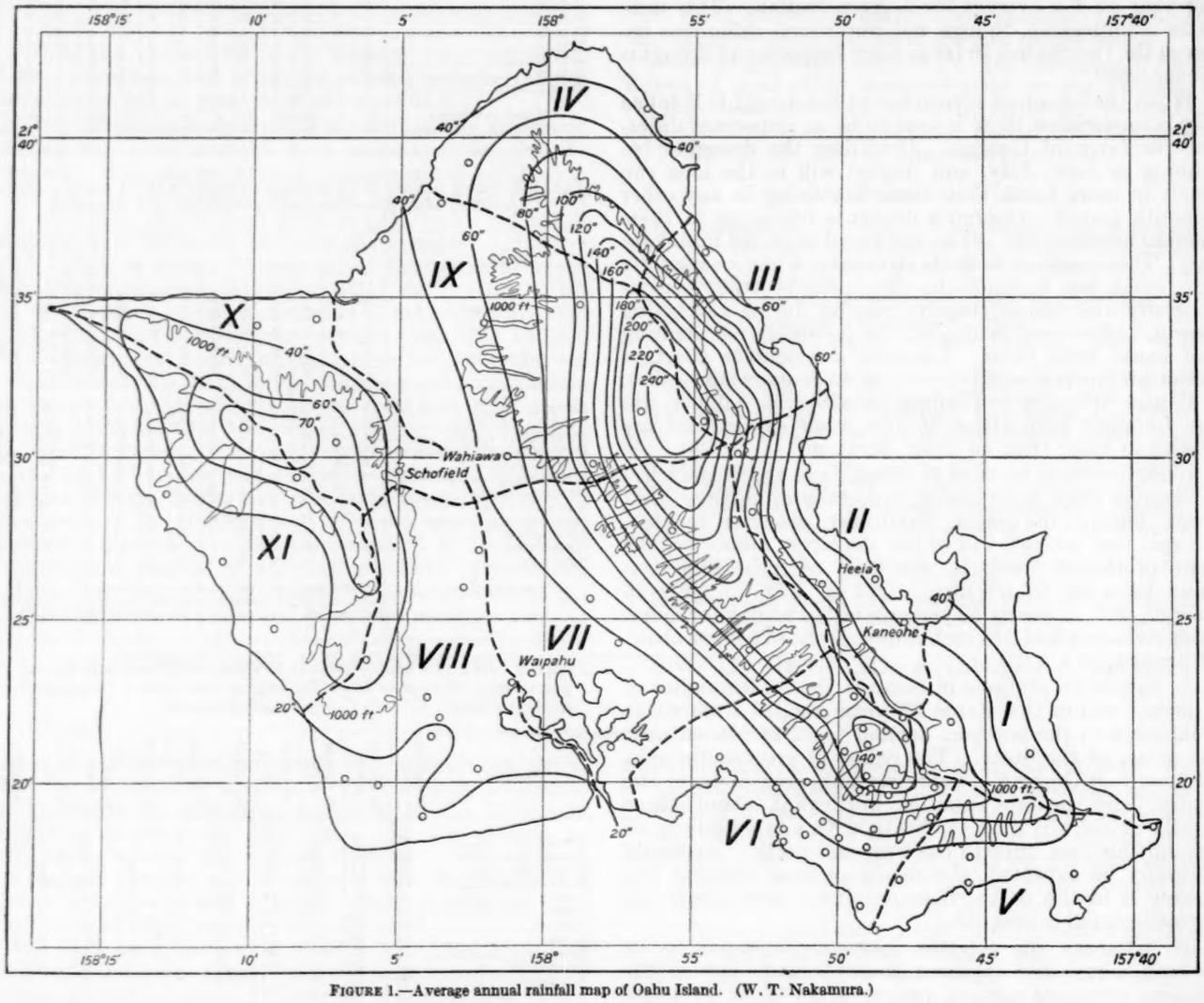

FIGURE 1.—Average annual rainfall map of Oahu Island. (W. T. Nakamura.)

It gives an idea of the variation from the average, but no general law can be given for this variation.

To study cyclical and progressive trends in annual rainfall the method of progressive means may be resorted to. The heavy line in figure 3 is drawn through the departures of progressive means of Honolulu (WBO) data which were calculated from the forumla:

$$c' = \frac{a+4b+6c+4d+e}{16}$$

where a, b, c, d, and e are the annual rainfalls of consecutive years and c' is the progressive mean for the year in which the rainfall was c. The dotted line joins points of departures of the actual rainfall from the average. While conclusive evidence is not shown, from this figure it is seen that maximum and minimum rainfalls tend to occur approximately every 14 years. However, this cycle is at best too indefinite to be of any value for forecasting rainfall in the future, as is apparent when the actual departures and departures of progressive means are compared in the figure. The time covered is too short for this kind of analysis.

Another and more detailed method of analyzing rainfall data which has been utilized by Allen Hazen (2) and Thorndike Saville (3) is based on the law of probabilities. While this method is by no means absolutely dependable much beyond the limits of experience, it has its value in interpreting the relation of rainfall to water engineering problems. A brief theoretical discussion is here presented, using the rainfall data for Honolulu (WBO) as an example.

Taking the frequency as ordinate and observed annual rainfall as abscissa where the class interval is 4 inches, we obtain the frequency polygons or histogram of figure 4. The lower of the 2 rows of figures along the abscissa axis designates the midpoints (class marks) of the class intervals.

Now it is shown in works of statistics (4) that if the true average of a series of N observations is Z, and a near

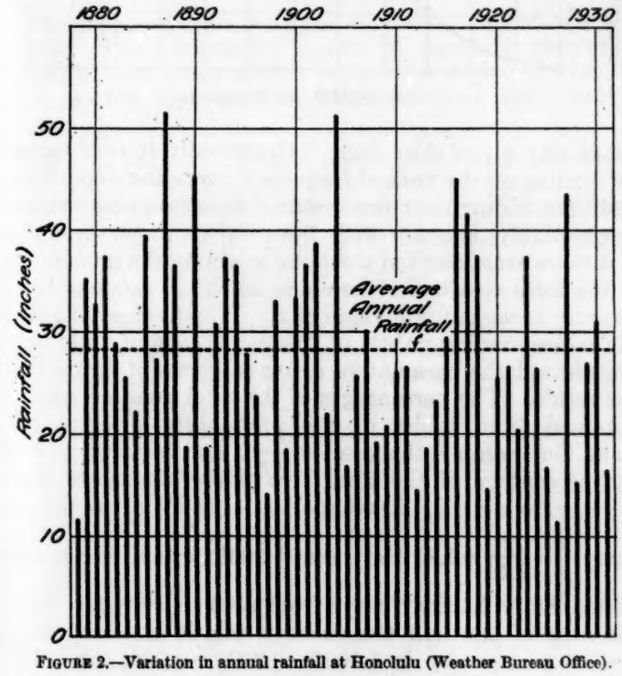

FIGURE 2.—Variation in annual rainfall at Honolulu (Weather Bureau Office).

average, or base value, taken arbitrarily is A; f, the class frequency, and c the departures of the class marks from A, then

$$Z = A + \frac{1}{N}\Sigma(fc) \qquad (1)$$

in class intervals. It is also shown that the index of variability of a distribution, σ called the standard deviation or standard variation is given by

$$\sigma = \sqrt{\frac{\Sigma(fc^2) - \Sigma(fc)}{N}} \qquad (2)$$

in class intervals.

The figures in column 1 of table 1 are the annual rainfalls at Honolulu (WBO) arranged in ascending order of magnitude. The limits of the class intervals into which these data were arranged are given under column 1 in table 2. Under column 2 (f) is given the frequency or number of times the annual rainfall fell in the different classes. Under column 3 (c) are given in class intervals the departures of the class marks from the arbitrary base value, A. Values for fc and fc^2 are products of f and c,

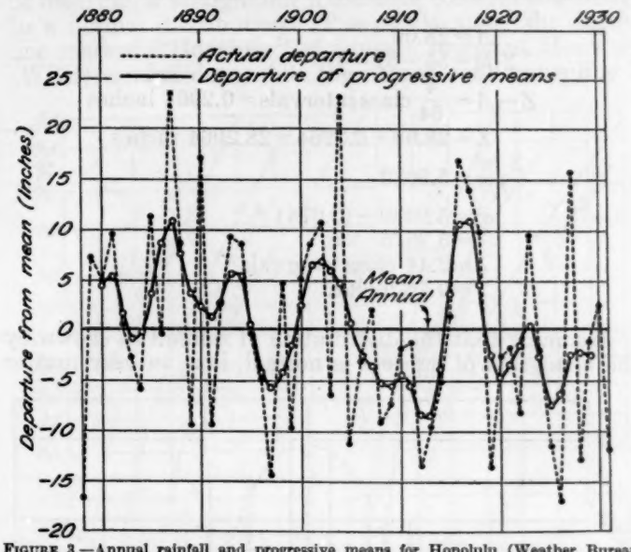

FIGURE 3.—Annual rainfall and progressive means for Honolulu (Weather Bureau Office).

and of f and c^2, respectively. The numerical computations for Z and σ are given below the data in table 2.

TABLE 1

Annual rainfall	Departure from base 28.21	Departure squared	Percentage of total years (cumulative)	Annual rainfall	Departure from base 28.21	Departure squared	Percentage of total years (cumulative)
In.	*In.*			*In.*	*In.*		
11.27	−16.94	286.96	0.926	27.63	−0.58	0.34	52.782
11.46	−16.75	280.56	2.778	27.97	−.24	.06	54.634
13.94	−14.27	203.63	4.630	28.99	+.78	.61	56.486
14.59	−13.62	185.50	6.482	29.64	+1.43	2.04	58.338
14.71	−13.50	182.25	8.334	30.13	+1.92	3.69	60.190
15.34	−12.87	165.64	10.186	30.78	+2.57	6.60	62.042
16.35	−11.86	140.66	12.038	31.04	+2.83	8.01	63.894
16.82	−11.39	129.73	13.890	32.87	+4.66	21.72	65.746
16.99	−11.22	125.89	15.742	32.88	+4.67	21.81	67.598
18.42	−9.79	95.84	17.594	33.21	+5.00	25.00	69.450
18.53	−9.68	93.70	19.446	35.26	+7.05	49.70	71.302
18.70	−9.51	90.44	21.298	36.49	+8.28	68.56	73.154
18.79	−9.42	88.74	23.150	36.70	+8.49	72.08	75.006
19.17	−9.04	81.72	25.002	36.77	+8.56	73.27	76.858
20.11	−8.10	65.61	26.854	37.23	+9.02	81.36	78.710
20.81	−7.40	54.76	28.706	37.34	+9.13	83.36	80.562
22.00	−6.21	38.56	30.558	37.46	+9.25	85.56	82.414
22.22	−5.99	35.88	32.410	37.57	+9.36	87.61	84.266
23.07	−5.14	26.42	34.262	38.71	+10.50	110.25	86.118
23.85	−4.36	19.01	36.114	39.55	+11.34	128.60	87.970
25.49	−2.72	7.40	37.966	41.64	+13.43	180.36	89.822
25.67	−2.54	6.45	39.818	43.52	+15.31	234.40	91.674
25.77	−2.44	5.95	41.670	44.96	+16.75	280.56	93.526
26.31	−1.90	3.61	43.522	45.12	+16.91	285.95	95.378
26.34	−1.87	3.50	45.374	51.34	+23.13	535.00	97.230
26.58	−1.63	2.66	47.226	51.62	+23.41	548.03	99.082
26.71	−1.50	2.25	49.078				
26.97	−1.24	1.54	50.930	Σ=1,523.40		Σ=5,419.39	

TABLE 2

Class interval	f	c	fc	fc^2
10–14	3	−4	−12	48
14–18	6	−3	−18	54
18–22	7	−2	−14	28
22–26	7	−1	−7	7
26–30	9	0	−51	
30–34	6	+1	+6	6
34–38	8	+2	+16	32
38–42	3	+3	+9	27
42–46	3	+4	+12	48
46–50		+5		
50–54	2	+6	+12	72
	$\Sigma=54$		+55	$\Sigma=322$

$$A=28.00$$
$$\Sigma fc=55-51=4$$
$$Z-A=\frac{4}{54}\text{class intervals}=0.2964\text{ inches}$$
$$Z=28.00+0.2964=28.2964\text{ inches}$$
$$\frac{\Sigma fc^2}{N}=5.9630$$
$$\sigma^2=5.9630-(0.0741)^2$$
$$=5.9575$$
$$\sigma=2.44\text{ class intervals}$$
$$=9.76\text{ inches}$$

Assuming that the distribution of rainfall as shown by the histogram of figure 4 is normal, it is an easy matter

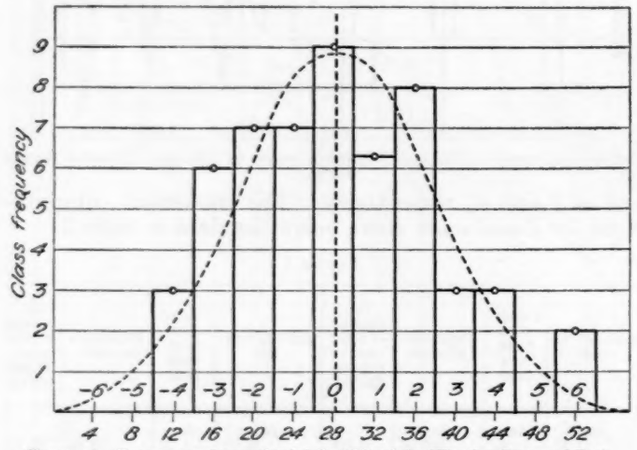

FIGURE 4.—Frequency of annual rainfall at Honolulu (Weather Bureau Office).

to obtain the curve of best fit. The equation of such a curve called the normal frequency curve is

$$y=\frac{N}{\sigma\sqrt{2\pi}}e^{-\frac{x^2}{2\sigma^2}} \qquad (3)$$

where y designates the frequency, e is the familiar base of the Napierian system of logarithms, x denotes in unit of class intervals the departure from the arithmetic mean, π is the constant 3.1416, and N and σ have the same meaning as designated above.

Substituting the values of the constants as found in the computations of table 2, in the above equation, we have

$$y=8.824e^{-0.0831x^2} \qquad (3')$$

Or putting it in logarithmic form for easy computation, we have

$$\log y=0.945665-0.036086x^2$$

The dotted curve of figure 4 is the curve of equation (3′). Values of x are the upper of the 2 rows of figures along the X axis.

This normal curve may be put into cumulative form. Such a curve would show the frequency of observations

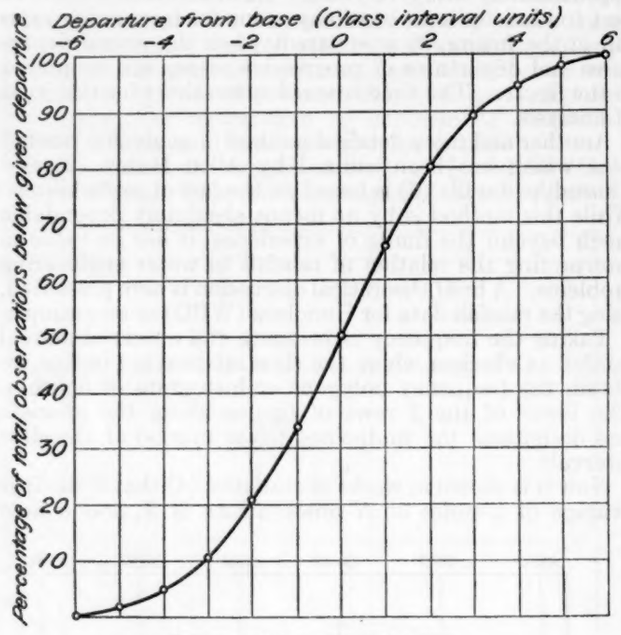

FIGURE 5.—Ogive or cumulative curve.

below any given class limit. Graphically it is obtained by reading on the normal frequency curve the departures and then adding the corresponding class frequency values progressively, starting with the smallest departures (**5**).

A more exact method would be to obtain the percentage of the total area under the curve to the X axis and from $x=-\infty$ to some finite value of x. When values of x and the corresponding values of the percentage of total area are plotted the cumulative or ogive curve of figure 5 is the result. The percentages of the total area are readily obtained from tables of the probability integral (**6**). Take, for example, the abscissa, -2, and required to find the percentage of the total area under the curve from $x=-\infty$ to $x=-2$. Davenport's table IV gives for the entry $\frac{x}{\sigma}=\frac{2}{2.44}=0.82$ the value 0.2939, which is the area under the probability curve from $x=0$ to $x=-2$. Since the area of one half the curve is 0.5000 the area from $x=-2$ to $x=-\infty$ is $0.5000-0.2939=0.2061$, or 20.61 percent (**7**).

In figure 5 if the abscissae had been expressed in units of σ, that is by $\frac{x}{\sigma}=t$, the ordinate could have been expressed by $\int_{-\infty}^{t}\frac{1}{\sqrt{2\pi}}e^{\frac{-t^2}{2}}dt$. To anamorphose the scale of the ordinate axis certain values of the above probability integral are taken between the limits $-\infty$ to t and placed opposite the corresponding values of t on the abscissa axis. The result is an anamorphosed ordinate scale and is called the probability scale. Or else, in

general, by assigning definite values to the probability integral and finding the limits of the integral, i.e., $t=\frac{x}{\sigma}$, we obtain the relative distances of the lines on the

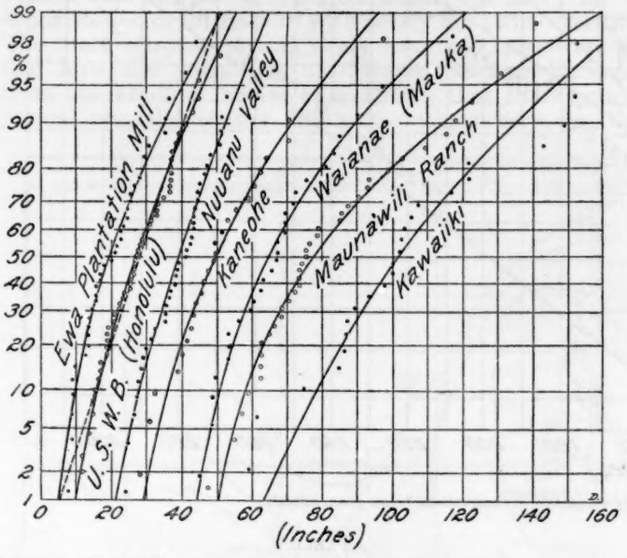

FIGURE 6.—Probabilities of annual rainfall. Probability percentage of observations below given rainfall

anamorphosed scale from the 50-percent line on the same scale. The cumulative curve of figure 5 becomes a straight line when drawn on such a scale. In figure 6 the dotted line marked "Honolulu" is the result of

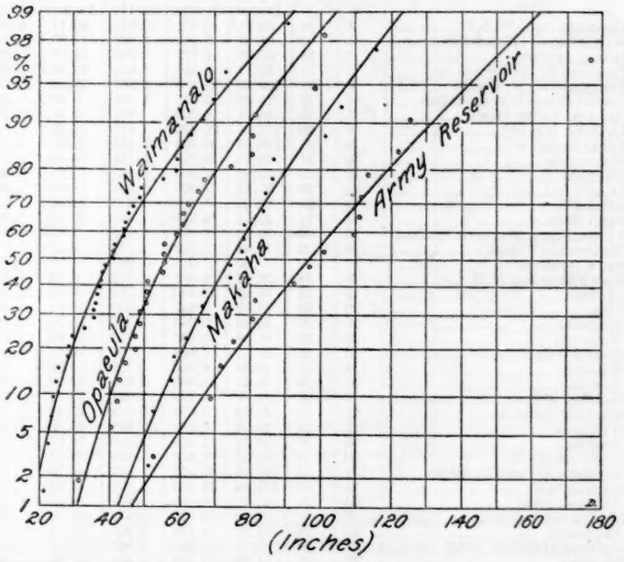

FIGURE 7.—Probabilities of annual rainfall. Probability percentage of observations below given rainfall.

drawing the curve of figure 5 on such a scale. The departures are not shown, however. They are easily gotten by adding or subtracting class interval units (4 inches for Honolulu [WBO] data) from the average.

In the above discussion it was shown that the ogive curve of a normal distribution of annual rainfall can be represented by a straight line by the use of probability paper; that is, coordinate paper with an anamorphosed scale as described above. At this point it is clear that instead of placing the rainfall into classes the actual rainfall arranged in ascending order may be used for the abscissa of the cumulative curve of figure 5. The corresponding ordinates would then be obtained as follows: since there are 54 observations, to each rainfall abscissa there corresponds an ordinate whose value is $\frac{100}{54}=1.852$ percent added cumulatively. In other words for the lowest rainfall abscissa the ordinate would be 1.852 percent; for the next lowest 2×1.852 or 3.704 percent; etc. The points were placed at the center of these percentage strips, that is, the first point at 0.926 percent; the second at 2.778 percent; etc.

These same data if plotted on probability paper would lie nearly on a straight line if the data conform essentially to a normal distribution. The points along the dotted line marked "Honolulu" of figure 6 represent Honolulu (WBO) rainfall data while the curved continuous line is

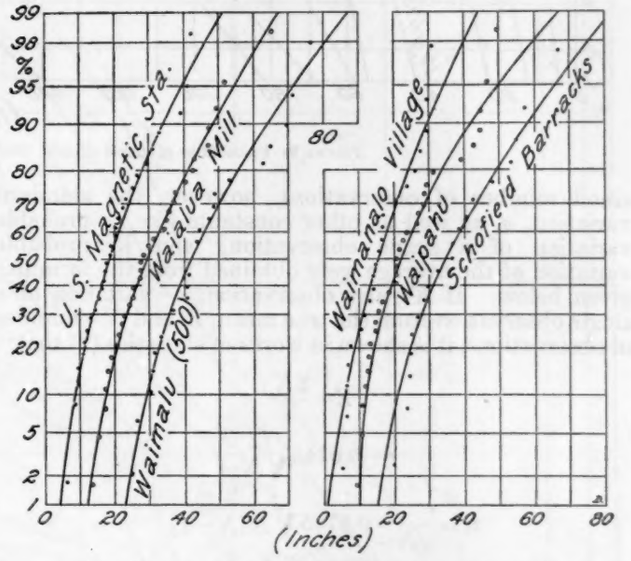

FIGURE 8.—Probabilities of annual rainfall. Probability percentage of observations below given rainfall.

an attempt to fit the data by inspection. The continuous curve departs slightly from the straight line and it means, therefore, that the rainfall distribution at Honolulu (WBO) departs somewhat from the normal; that is, the distribution is skewed.

In this study as mentioned above the curve was drawn by inspection, and no attempt was made to obtain a computed curve. Figures 6 to 9 show similar curves for 26 stations on Oahu Island. No doubt some of these would be closer fitted by skew curves, but the data are not sufficiently skewed to justify this refinement (8).

From these curves the probable frequency of occurrence of any given amount of rainfall can be obtained. The probable frequency of occurrence is equal to $\frac{100}{\text{percentage of years}}$. Table 3 gives the limiting rainfalls for 6 values of this frequency for 8 stations. It was comparatively easy to project lines to the data for these stations because of the greater number of observations, and the curves, therefore, may be considered as best-fit curves for practical purposes.

In the discussion thus far an attempt has been made to show how the dotted line of figure 6 is obtained by putting the annual rainfall into 4-inch classes. Because of the

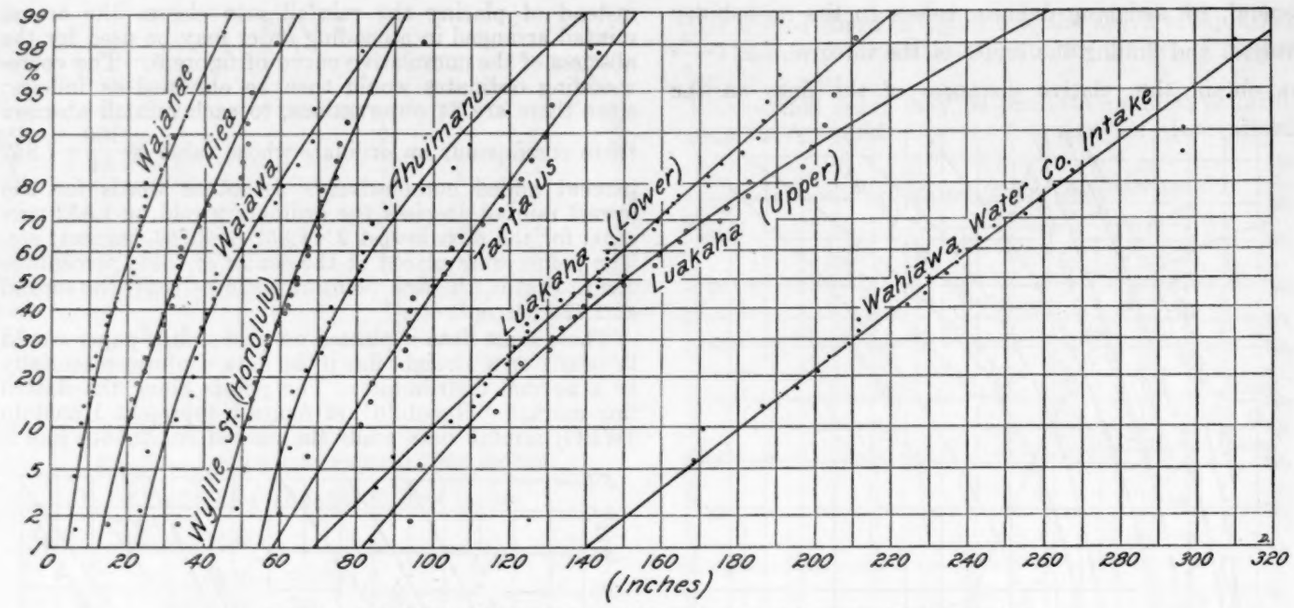

FIGURE 9.—Probabilities of annual rainfall. Probability percentage of observations below given rainfall.

small number of observations, however, the standard variation, σ, as well as other constants like r = probable variation of a single observation,[1] and R = probable variation of the average were obtained from the formulas given below. If K = any observation, v = variation of a single observation from the true mean, Z, and N = number of observations, it is shown in works of statistics **(9)** that:

$$Z = \frac{\Sigma K}{N}$$

$$r = 0.6745\sqrt{\frac{\Sigma v^2}{N-1}}$$

$$R = \frac{r}{\sqrt{N}} = 0.6745\sqrt{\frac{\Sigma v^2}{N(N-1)}}$$

$$\sigma = \sqrt{\frac{\Sigma v^2}{N-1}}$$

TABLE 3.—*Limiting rainfalls for 6 values of the probability of occurrence at 8 stations on Oahu Island*

Percentage of years Probable frequency, once in	25 4 years	15 6.7 years	10 10 years
Honolulu (W.B.O.)	20− or 34+	18− or 39+	16− or 41+
Ewa Plantation Mill	14− or 27+	11− or 32+	10− or 35+
Wahiawa Water Co. intake	205− or 258+	192− or 274+	182− or 284+
Waianae	13− or 26+	10− or 30+	9− or 33+
Waialua Mill	22− or 39+	19− or 44+	18− or 48+
Waimanalo	31− or 53+	27− or 60+	25− or 65+
Nuuanu Valley	33− or 46+	30− or 50+	28− or 53+
Luakaha (lower)	119− or 163+	108− or 175+	100− or 184+

Probable frequency, once in	5 20 years	2 50 years	1 100 years
Honolulu (W.B.O.)	13− or 46+	11− or 52+	10− or 56+
Ewa Plantation Mill	8− or 40+	6− or 47+	5− or 52+
Wahiawa Water Co. intake	168− or 298+	151− or 314+	140− or −*
Waianae	7− or 37+	6− or 43+	5− or 46+
Waialua Mill	15− or 55+	14− or 62+	12− or 67+
Waimanalo	22− or 74+	−* or 85+	−* or 92+
Nuuanu Valley	25− or 57+	22− or 62+	20− or 65+
Luakaha (lower)	89− or 196+	77− or 210+	70− or 220+

* Undetermined.

[1] Books on statistics usually give $r = 0.6745\sqrt{\frac{\Sigma v^2}{n}}$. This formula is applicable with a large number of observations, n. When n is small as it is in this work, the formula retaining the term $(n-1)$ is more accurate.

TABLE 4

Station name	Station no.	Number of observations	Average annual rainfall	Probable variation of single observation	Probable variation of average	Standard variation (σ)	Coefficient of variation
			Inches	*Inches*	*Inches*	*Inches*	*Inches*
Honolulu (U.S.W.B.)	1	54	28.21	6.821	0.928	10.11	0.358
Wyllie Street (Honolulu)	2	30	64.07	8.150	1.488	12.08	.189
Insane Asylum	3	34	37.97	7.929	1.360	11.76	.310
Punahou (C. J. Lyons)	4	21	38.14	7.404	1.616	10.98	.288
Tantalus (W. F. Frear)	5	24	102.16	13.550	2.767	20.10	.197
United States Naval Station	6	27	24.40	6.041	1.163	8.96	.367
Nuuanu Valley (Hall)	7	39	40.04	6.209	.994	9.21	.230
Luakaha (upper)	8	28	152.56	22.830	4.314	33.85	.222
Luakaha (lower)	9	41	140.88	20.280	3.168	30.07	.214
Waimanalo	10	37	43.25	10.790	1.774	16.00	.370
Kaneohe	11	26	52.80	11.560	2.267	17.14	.324
Moanalua	12	26	33.72	7.926	1.554	11.75	.349
Puuloa	13	29	20.63	7.308	1.357	10.84	.525
Pearl Harbor	14	17	21.76	6.813	1.652	10.10	.464
United States Magnetic Station	15	30	19.99	6.681	1.220	9.90	.496
Waimanalo Village	16	22	16.48	5.529	1.179	8.20	.497
No. 6 Reservoir	17	22	17.80	5.936	1.266	8.80	.494
Ewa Plantation Mill	18	38	20.92	6.487	1.052	9.62	.460
Apokaa	19	22	20.01	6.450	1.375	9.56	.478
Aiea	20	30	34.13	7.647	1.396	11.34	.332
Waimalu	21	29	35.49	9.298	1.727	13.79	.388
Waiawa	22	22	47.98	9.999	2.132	14.82	.309
Hoaeae (upper)	23	24	35.21	8.648	1.765	12.82	.364
Waianae	24	33	19.93	6.460	1.125	9.58	.481
Makaha	25	20	76.31	11.800	2.639	17.50	.229
Waialua Mill	26	32	31.39	8.279	1.464	12.27	.391
Schofield Barracks	27	19	37.22	9.079	2.083	13.46	.362
Wahiawa	28	18	46.30	10.360	2.441	15.36	.332
Opaeula	29	28	59.31	11.410	2.156	16.91	.285
Army Reservoir	30	16	99.35	19.810	4.953	29.37	.296
Wahiawa Water Co. intake	31	26	231.76	30.150	5.913	44.70	.193
Kahana (800)	32	15	243.60	32.060	8.278	47.53	.195
Waimalu (500)	33	24	45.42	9.683	1.977	14.36	.316
Maunawili Ranch	34	37	82.00	15.010	2.468	22.26	.272
Ahuimanu	35	21	83.00	14.720	3.211	21.81	.263
Waianae (Mauka)	36	28	68.17	10.940	2.067	16.21	.238
Pupukea	37	16	52.49	10.160	2.540	15.06	.287
Makapuu Point	38	17	24.40	9.909	2.403	14.69	.602
Kawailiki	39	24	104.12	17.480	3.568	25.91	.249
Kahuku	40	39	37.40	8.646	1.385	12.82	.343
Aiea (500)	41	23	41.59	9.424	1.965	13.97	.336
Waipahu	42	31	24.06	7.961	1.430	11.80	.490

In table 1 under column 1 are shown in the order of magnitude the annual rainfall at Honolulu. The departure from the mean (v), the square of the departure (v^2), and the percentage of the whole observations or total years which had rainfall below the corresponding annual rainfall are given in the other (3) column.

From this table and from the formulas above, it was found that for Honolulu $Z=28.21$, $\sigma=10.11$, $r=6{,}821$, and $R=0.928$.

The standard variation, σ, gives a good idea of how the annual rainfalls are distributed about the mean for a single station or for stations with nearly the same average. The main purpose of this study has been, however, to find how the variations at different stations differed from one another. Since it is known that the average annual rainfalls at the different stations vary greatly

The coefficient of variation is strictly speaking a measure of variability for normal distributions. No meaning is attached to it if it is used for comparing distributions of varying degrees of skewness except that it is the coefficient of variation for a normal frequency curve of best fit to the data. However, for distributions of about the same degree of skewness it may still be used as a comparative measure of variation. In figures 6 to 9 an idea of the extent of the departure of the distribution from the normal distribution may be gained from the

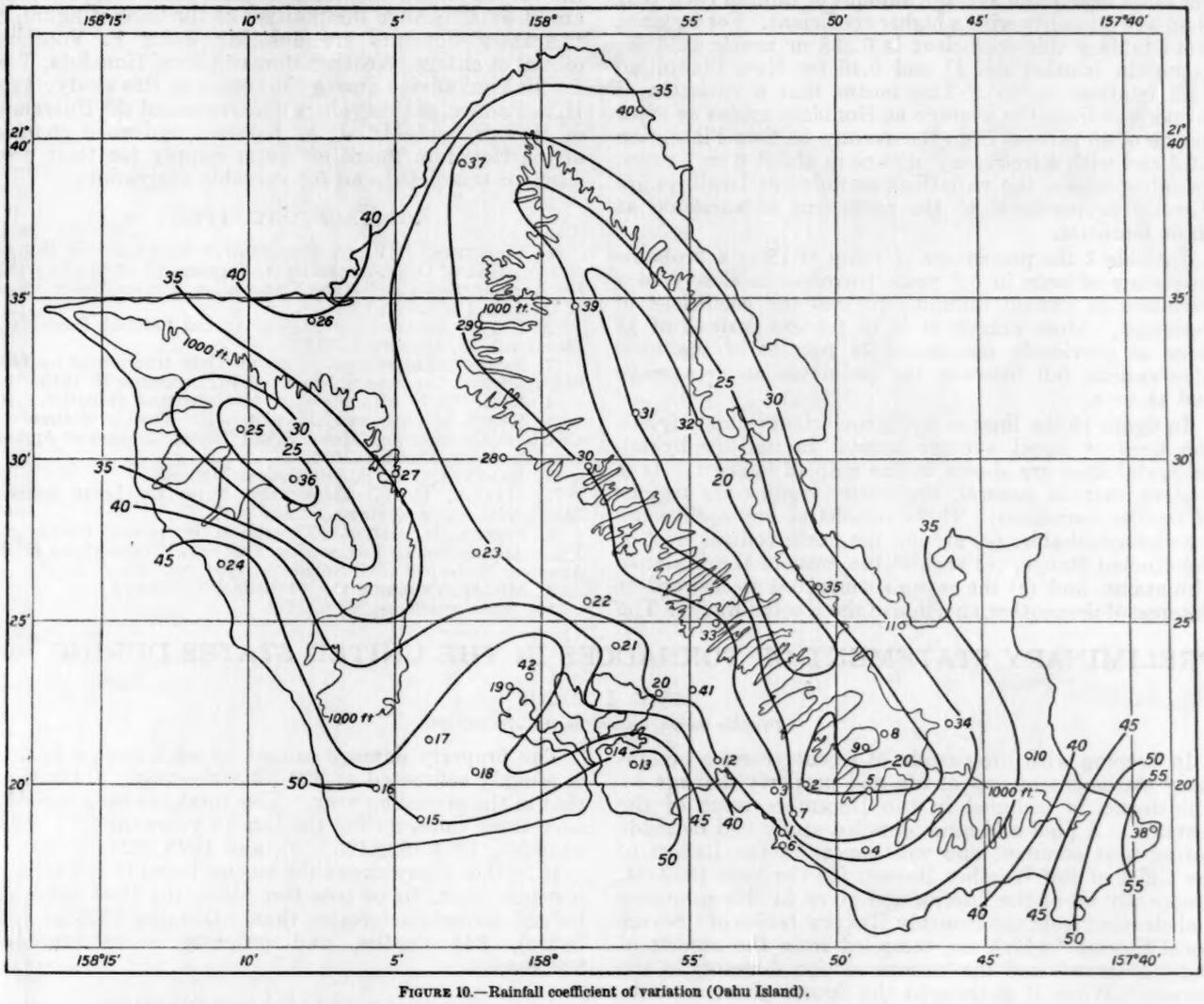

FIGURE 10.—Rainfall coefficient of variation (Oahu Island).

some measure of variability other than σ was, therefore, needed which would take into account the average from which the deviations are calculated. The desired measure or coefficient of variation is the ratio of the standard variation to the average or expressed in symbols $\frac{\sigma}{M}$. This coefficient as well as σ, R, and r have been calculated for 42 stations on Oahu Island, and they are given in table 4.

In figure 10 lines were drawn through places of equal coefficients. The smaller numbers are station numbers as given in table 4, while the larger numbers are the coefficients.

extent to which the continuous curves depart from the straight lines drawn through the points, $x=$arithmetic average, $y=50$ percent and $x=\sigma$, $y=34$ percent since in a normal distribution 34 percent of the observations are enclosed by the ordinates at $x=$average and at $x=\sigma$. It can be shown, moreover, that the distance along the average ordinate (on the percentage of time scale) from the 50 percent line to the point where the curve crosses the average ordinate is a measure of the coefficient of skewness of the distribution. The straight lines mentioned above are not shown in figures 6 to 9 except for Honolulu.

H. Alden Foster (**10**) states that the coefficient of variation can be computed with considerable accuracy

from a record of moderate length but that the coefficient of skewness cannot be computed with any degree of precision except from a very long record. However, he shows that for practical work an average coefficient of skew may be assumed as applicable to data of all the stations. This average coefficient was not determined in this study. Whatever it may be, with the same coefficient of skewness for all stations, the coefficient of variation can be used as a measure of variability.

Any locality with a low coefficient of variation will get more nearly the average amount of rainfall each year than will a locality with a higher coefficient. For instance from table 4 this coefficient is 0.358 or nearly 0.36 for Honolulu (station no. 1) and 0.46 for Ewa Plantation Mill (station no. 18). This means that a variation of 36 percent from the average at Honolulu comes as often as one of 46 percent from the average at Ewa Plantation Mill and with a frequency of once in about 6 or 7 years. In other words, the variations at different localities are directly proportional to the coefficient of variation at those localities.

In table 3 the percentage of years of 15 or a probable frequency of once in 6.7 years corresponds closely to a variation in annual rainfall equal to the coefficient of variation. More exactly it is 16 percent instead of 15 since as previously mentioned 34 percent of the total observations fall between the ordinates at x=average and at $x=\sigma$.

In figure 10 the lines of equal coefficients closely follow the lines of equal average annual rainfall (isohyets). Isohyetal lines are shown in the map of figure 1. It is evident that, in general, the wetter regions are regions of smaller variations. Three regions of low coefficients are distinguishable: (*a*) around the north central crest of the Koolau Range, (*b*) around the crest of the Waianae Mountains, and (*c*) the regions somewhat to leeward of the crest of the southern portion of the Koolau Range. The first region incloses the wettest area of Oahu Island, the average annual rainfall being 240 inches. In the third region coefficients are equally low although the average annual rainfall is about 140 inches. The region to the south and southwest of Pearl Harbor has the highest variability, and it is also the driest region of the island.

Like the maps of isohyetal lines the map of figure 10 should be regarded as an approximation in view of the character of the topography. Great differences in annual rainfall are noticeable over short distances; likewise, in the coefficients of variation, so that more complete data are likely to change the position of the lines of figure 10.

Acknowledgments are due Mr. John F. Voorhees, official in charge, Weather Bureau Office, Honolulu, T.H. for his kind advice during the course of this study; Prof. H. S. Palmer, of the geology department of the University of Hawaii, and Mr. J. F. Kunesh, hydraulic engineer of the Honolulu Board of Water Supply for their criticisms of this paper and for valuable suggestions.

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PRELIMINARY STATEMENT OF TORNADOES IN THE UNITED STATES DURING 1933

By R. J. MARTIN
[Weather Bureau, Washington, D.C., January 1934]

In keeping with the custom of recent years, a preliminary statement of loss of life and property damage by windstorms is included in the December issue of the REVIEW. A final and more detailed study will be made during next summer, and will appear in the Report of the Chief of the Weather Bureau for the year 1933–34. Practically all of the information given in this summary is abstracted from the monthly REVIEW tables of "Severe Local Storms" which are compiled from the reports of many observers and the various section directors of the Bureau. While it is thought the figures given are substantially correct it must be remembered that all are subject to change after the final study mentioned above.

May, with 73 (possibly 80) tornadoes and 205 fatalities, was the month with the greatest number of storms and greatest loss of life. The second highest figures occurred in March, with 33 tornadoes and 95 deaths. Both these months were exceeded in property damage by April; during which month there were 26 storms and a property loss of nearly $10,000,000.

The total number of tornadoes during the year, 197, was considerably greater than in 1932. This figure has been exceeded only twice (1928 and 1929) during the last 18 years. The total number of deaths resulting from the 1933 storms was 343, which is considerably less than the 1932 number (394) and far less than the 1925 and 1927 figures (794 and 540, respectively).

The property damage caused by such storms in 1933 is roughly estimated at $22,180,000—nearly three times that of the preceding year. This total has been exceeded only three times during the last 18 years, in 1927 ($43,445,650), 1924 ($26,120,850), and 1925 ($24,023,900).

If further study shows the storms listed in the table of tornadic winds to be true tornadoes, the 1933 sums will be 220 tornadoes (greater than either the 1928 or 1929 figure), 344 deaths, and property losses exceeding $23,908,000.

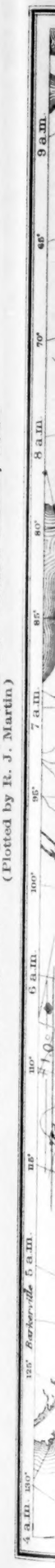
TORNADOES AND PROBABLE TORNADOES

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Number	10	4	33	26	73	14	11	10	5	5	1	5	197
Deaths	4	0	95	20	205	2	7	1	0	3	0	6	343
Damage [1]	1,136	37	3,362	9,645	7,046	181	613	110	6	8	2	[2] 34	22,180

TORNADIC WINDS AND POSSIBLE TORNADOES [3]

Number	0	0	1	1	7	5	7	1	1	0	0	0	23
Deaths	------	----	0	0	0	1	0	0	0	----	----	----	1
Damage [1]	------	----	1	1	1,215	365	[2] 106	40	[4] 0	----	----	----	1,728

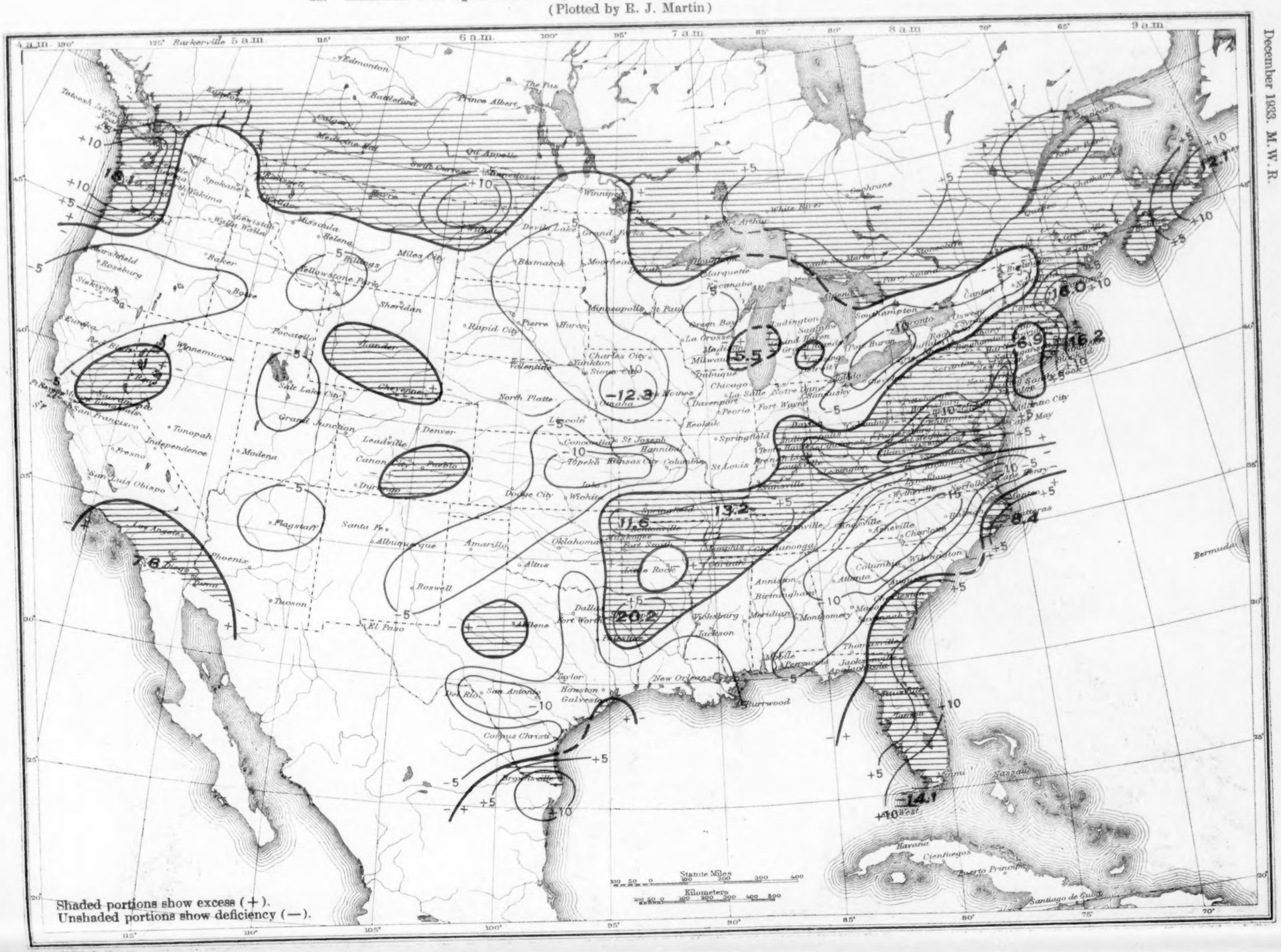
[1] In thousands of dollars.
[2] Damage occurred in addition to amount stated.
[3] Some of these may not be classed as tornadoes in the final study.
[4] Damage occurred; no estimate secured.



I. Annual Temperature Departures (°F.) in the United States, 1933
(Plotted by R. J. Martin)

II. Annual Precipitation Departures (inches) in the United States, 1933

(Plotted by R. J. Martin)



THE WEATHER OF 1933 IN THE UNITED STATES

By R. J. MARTIN
[Weather Bureau, Washington, D.C., January, 1934]

The year 1933 was considerably warmer than normal. The average temperature, for all States, was +1.8° above normal, an excess twice that of 1932. Precipitation was below normal in nearly all sections; the average for the entire area was 2.4 inches less than that of the preceding year.

In keeping with trends for a long time past, temperatures were abnormally high over most of the country. Only the south Pacific district (California, from Fresno southward to San Diego) averaged below normal for the year, and here the deficiency was only −0.3°. The middle Pacific district (California, from San Francisco northward to Eureka) averaged exactly normal. Elsewhere temperature departures for 1933 were positive and ranged from +0.1° over the north Pacific area to +3.5° over the middle slope and +3.6° in the Missouri Valley.

Only 2 months of the year (February and April) were colder than normal for the entire United States. February, with a departure of −1.3°, was 6° colder than in 1932. The relatively coldest weather occurred in the middle plateau, where this month averaged 13° below normal. It was also in February that a new minimum temperature record for the United States was made when Riverside ranger station, in Yellowstone Park, Wyo., reported −66° on the 9th.

The three relatively warmest months were January, with a departure of +5.8°; December, +3.4°; and June, +3.3°. No single month averaged above normal in every district. Every State reported maximum temperatures of 100° or higher during the summer except Maine, New Hampshire, and Rhode Island, and in these three the maxima ranged between 95° and 99°. The highest temperature of the year was 127° at Greenland Ranch, Calif., on August 12. Using the Wyoming minimum and the California maximum the temperature range for the year was 193°.

The deficiency in precipitation averaged, for all States, over 2 inches. Only 5 of the 21 reporting districts were above normal for the whole year, and except for the North Pacific area and the Ohio Valley and Tennessee, these districts were along the Atlantic coast. The comparatively wettest area, 8.2 inches above the annual average, was the Florida peninsula; the second largest excess, 4.2 inches, occurred in the North Pacific States. Departures in the three other wetter-than-normal areas were comparatively small.

Chart 2 shows that practically all the northern, southern, western, and interior portions of the country were drier than normal. Deficiencies ranged from less than 1 inch in the South Pacific area to nearly 9 inches over the southern slope (portions of western Texas and New Mexico). In the east Gulf area the rainfall was over 7 inches subnormal, and both the lower Lake and the South Atlantic districts had large deficiencies. In at least 6 sections (east Gulf, North Dakota, Missouri Valley, the middle and southern slopes, and the middle and northern plateaus) there was less rain than in the dry year 1930.

Six of the twelve months averaged, for all States, wetter than normal, while July was exactly normal.

The wet months were March, April, May, August, September, and October; in May, the comparatively wettest month, the departure was only +0.23 inch. Two (June and November) of the five dry months averaged more than 1 inch subnormal. The largest monthly excess for any district was +7.8 inches for October in the Florida peninsula. The largest monthly deficiency was −2.7 inches in February in the middle Pacific area.

Some unusually heavy rains occurred during the year, notably in Louisiana and eastern Texas on July 22–25, and in southern California during the last week of the year. At several points in Louisiana and Texas the 4-day totals during the July rain exceeded 20 inches. Damage, mostly to crops, caused by this rain was estimated at nearly 2 million dollars. The California rain is discussed in the table of Severe Local Storms.

Snowfall was generally subnormal, but there were some instances of unusually large amounts. For example, at Crater Lake, Oreg., the total snowfall for the winter of 1932–33 was 879 inches, 250 inches of which fell in 1932. This total is only 5 inches less than the record seasonal fall for the United States of 884 inches at Tamarack, Calif., during the winter of 1896–97.

Floods, hurricanes, and other outstanding features of the weather of 1933 are discussed elsewhere in this issue of the REVIEW.

TABLE 1.—*Monthly and annual temperature departures, 1933*

District	January	February	March	April	May	June	July	August	September	October	November	December	Average
New England	+9.7	+4.7	+0.2	+0.4	+2.5	+1.8	−0.6	+1.0	+2.0	−0.4	−3.9	−5.2	+1.0
Middle Atlantic	+9.4	+2.8	+.2	+1.3	+3.0	+2.5	−.4	+.6	+3.7	−.4	−1.9	+1.0	+1.8
South Atlantic	+7.2	+1.5	+1.1	+.2	+4.6	+1.7	−.8	+.8	+5.2	+1.1	−.5	+6.2	+2.4
Florida Peninsula	+3.3	+4.6	+.6	+2.3	+3.1	−.5	+.5	+.8	+1.9	+.9	−1.5	+3.4	+1.6
East Gulf	+6.7	−.2	+.6	−.4	+4.6	+.5	−.9	+.7	+4.7	+1.6	+1.0	+8.9	+2.3
West Gulf	+8.2	−1.9	+1.5	+.9	+3.3	+.7	+.5	.0	+4.4	+2.8	+3.4	+8.0	+2.6
Ohio Valley and Tennessee	+9.1	+.2	−.4	+.1	+2.8	+4.0	+.6	−.4	+5.0	−1.0	−.8	+5.0	+2.0
Lower Lakes	+10.8	+3.5	+.2	+1.9	+2.4	+4.6	+2.3	+.4	+3.0	−1.5	−4.2	−1.2	+1.8
Upper Lakes	+9.6	+.1	+.5	+.1	+1.9	+6.2	+2.6	+.7	+4.7	−1.9	−4.3	−2.5	+1.5
North Dakota	+7.6	+.6	+6.8	−.2	+1.6	+8.5	+4.4	+3.1	+4.4	−2.3	+1.5	−4.4	+2.6
Upper Mississippi Valley	+13.2	−.1	+1.2	−.4	+.9	+8.2	+2.3	−.3	+5.9	−1.4	+.1	+2.9	+2.7
Missouri Valley	+13.3	+.4	+2.5	+.6	+.4	+8.9	+3.1	−.4	+5.7	+.2	+3.6	+5.3	+3.6
Northern Slope	+6.1	−3.7	+4.2	−1.8	−1.5	+6.9	+4.7	+.4	+1.9	+3.7	+5.6	+5.4	+2.7
Middle Slope	+9.6	−1.5	+2.7	−.5	+.8	+6.9	+3.1	−.4	+5.1	+2.8	+5.0	+8.0	+3.5
Southern Slope	+5.7	−2.8	+2.6	−.7	+1.3	+1.8	+2.5	+1.3	+5.8	+5.0	+3.8	+7.1	+2.8
Southern Plateau	−2.9	−6.6	+1.8	−2.4	−2.9	+1.0	+3.1	+2.2	+4.6	+5.7	+3.2	+4.2	+.9
Middle Plateau	−2.7	−13.0	+.3	−2.1	−4.0	+5.0	+5.3	+1.5	+3.5	+7.2	+2.0	+6.8	+.8
Northern Plateau	+3.3	−8.7	−1.0	−1.0	−3.3	+2.9	+3.4	+1.9	−1.3	+5.4	+2.0	+9.1	+1.1
North Pacific	−.4	−3.2	.0	−.3	−2.1	+.1	+.2	+1.9	−1.6	+1.9	+.6	+3.6	+.1
Middle Pacific	−3.5	−2.4	+.8	+.2	−2.7	−.5	+2.4	+1.5	−.5	+3.4	+2.0	−.1	.0
South Pacific	−1.6	−1.3	+1.2	−.1	−2.9	−2.0	+.3	−.5	−3.2	+2.5	+3.5	.0	−.3
United States	+5.8	−1.3	+1.3	−.1	+.7	+3.3	+1.8	+.8	+3.1	+1.7	+1.0	+3.4	+1.8

TABLE 2.—*Precipitation departures, monthly and annual, 1933*

District	January	February	March	April	May	June	July	August	September	October	November	December	Sum
New England	−1.3	+0.4	+1.5	+2.4	−0.8	−0.6	−1.6	+0.7	+2.7	+0.8	−1.6	+0.3	+2.9
Middle Atlantic	−.9	−.5	+.4	+1.1	+1.1	−.9	−.2	+4.4	+.4	−1.4	−1.5	−.8	+1.2
South Atlantic	−1.1	+.6	−1.5	+.3	−.2	−2.3	+.1	+.1	+1.8	−.1	−1.3	−2.5	−6.1
Florida Peninsula	−2.0	+.4	+.2	+1.7	−1.8	+2.1	+2.2	+1.8	−1.2	+7.8	−1.6	−1.4	+8.2
East Gulf	−1.3	+1.6	+.7	+2.3	−1.6	−1.3	+1.8	−2.2	−2.0	−.9	−1.9	−2.3	−7.1
West Gulf	−.1	+.3	+.4	−1.4	.0	−2.6	+4.0	+.3	+.8	−1.0	−1.4	−.5	−1.2
Ohio Valley and Tennessee	−.8	.0	+1.7	+.3	+3.3	−2.0	+.2	+.7	+.9	−1.3	−1.8	+.3	+1.5
Lower Lakes	−1.3	−.7	+.6	+.3	+.5	−2.0	−1.6	+.1	−.1	−1.2	−.4	−.5	−6.3
Upper Lakes	−.4	.0	+.1	+.8	+.8	−.8	−.4	−1.7	+.1	+.6	−.5	−.1	−1.5
North Dakota	+.3	−.2	−.4	−.3	+.2	−1.9	−.5	−1.6	−.8	−.5	+.1	+.7	−4.9
Upper Mississippi Valley	+.2	−.7	+1.3	−.4	+2.8	−2.1	−.4	−1.2	+.4	−.5	−1.5	−.4	−2.5
Missouri Valley	−.2	−.8	+1.0	−.6	−.4	−2.1	−.7	+.3	+.3	−1.3	−.9	+.3	−5.1
Northern Slope	−.2	−.2	−.2	+1.0	+.4	−1.3	−.9	+1.2	−.2	−.4	−.2	+.1	−.9
Middle Slope	−.5	−.4	+.2	+.6	−.7	−2.0	−.7	+1.6	−.2	−.8	−.3	+.3	−2.9
Southern Slope	−.4	.0	−.5	−1.4	.0	−2.0	−1.8	+.3	−1.4	−1.2	+.1	−.4	−8.7
Southern Plateau	+.5	−.5	−.5	+.2	−.2	+.6	−.4	−.5	.0	.0	−.2	−.5	−1.5
Middle Plateau	+.4	−.6	−.5	−.6	+.2	−.5	+.3	−.1	−.3	.0	−.4	−.2	−2.3
Northern Plateau	−.3	−.4	−.3	−.4	.0	−.5	−.3	−.1	.0	.0	−.8	+.7	−2.4
North Pacific	+1.3	−1.9	+1.7	−1.9	+.8	−.2	.0	−.1	+1.4	+.4	−3.0	+5.7	+4.2
Middle Pacific	+.1	−2.7	−.3	−1.6	+.4	−.2	.0	.0	−.4	.0	−3.0	+1.8	−5.9
South Pacific	+2.7	−2.0	−1.5	−.2	.0	+.1	.0	.0	−.2	−.2	−.9	+1.7	−.5
United States	−.3	−.4	+.2	+.1	+.2	−1.1	.0	+.2	+.1	−.1	−1.1	+.1	−2.1

TROPICAL STORMS OF 1933

By G. E. DUNN

[Weather Bureau, Washington, February 1934]

Twenty-one tropical disturbances were reported this year in the Caribbean Sea, the Gulf of Mexico, and the southern portion of the Atlantic. This is the largest number observed in any one season in 46 years of record. Hitherto 16, in 1887, had been the greatest number; since that time only 9 years have reported 10 or more.

The Mexican coastal area suffered the most from these storms, for no less than 5 intense hurricanes and 2 lesser tropical disturbances crossed its coastline. Immense damage was done in and about Tampico from the two hurricanes that passed almost directly over that city. Two fully developed hurricanes and two minor storms crossed the Yucatan peninsula, but no large cities were in their paths and reports of damage are meager. The middle Atlantic coast was buffeted once in August and again in September. The earlier storm crossed the coastline at Cape Hatteras and later passed directly over Washington with diminished intensity. This was one of the most destructive storms in the history of the middle Atlantic coast. As the September storm was recurving to the northeast, the center barely touched the North Carolina coast causing great damage in the New Bern section. Two hurricanes crossed the coastline near the mouth of the Rio Grande; the September storm caused enormous damage. The June hurricane which touched the north coast of Venezuela was the earliest known in that region and the only one to pass south of the island of Trinidad in 50 years of record.

Complete accounts of the majority of these storms may be found in the monthly issues of the REVIEW during the past year (1933).

Monthly frequency of West Indian hurricanes and other tropical storms of the North Atlantic Ocean in 1933

	Hurricane intensity	Doubtful	Not of hurricane intensity	Total
May	0	1	0	1
June	1	0	0	1
July	1	0	2	3
August	3	1	3	7
September	3	0	2	5
October	2	1	0	3
November	0	1	0	1
Total	10	4	7	21

Synopsis of tropical storms of 1933. (Number of storm in table corresponds with number of track on accompanying chart)

Storm	Date	Place where first reported	Coast lines crossed	Maximum wind velocity reported	Lowest barometer reported	Place of dissipation	Intensity	Remarks
	1933			*Mi. per hr.*	*Inches*			
1	May 13–18	Western Caribbean.[1]	None	Steamship *Sinaloa*, 50.	Steamship *Sinaloa*, 29.58.	Southwestern Gulf of Mexico.	Probably not of hurricane intensity.	
2	June 27, July 6	Short distance north of Guiana.[2]	De Paria Peninsula, Venezuela; Mexican coast midway between Brownsville, Tex., and Tampico, Mexico.	Hurricane winds over most of path.	Steamship *Texas City*, 28.42.	Interior of Mexico	Hurricane	Earliest known in Trinidad area and the only one in a record of 50 years to pass south of that island.
3	July 13–19	Near St. Kitts	Yucatan Peninsula and Mexico somewhat north of Vera Cruz.			do	Minor disturbance.	
4	July 21–27	Western Gulf of Mexico.[1]	Texas between Galveston and Corpus Christi.			Near Memphis	do	Torrential rains over portions of Texas and Louisiana.
5	July 25, Aug. 5	Short distance south of Antigua.[2]	Florida, short distance south of Fort Pierce; later Texas and Mexico slightly south of Brownsville.	85 NE. Turks Island, 72 NW. Brownsville, Tex.	About 29.00 Brownsville, 29.02 Saba Island.	Interior of Mexico	Hurricane	

[1] Approximate place of origin.

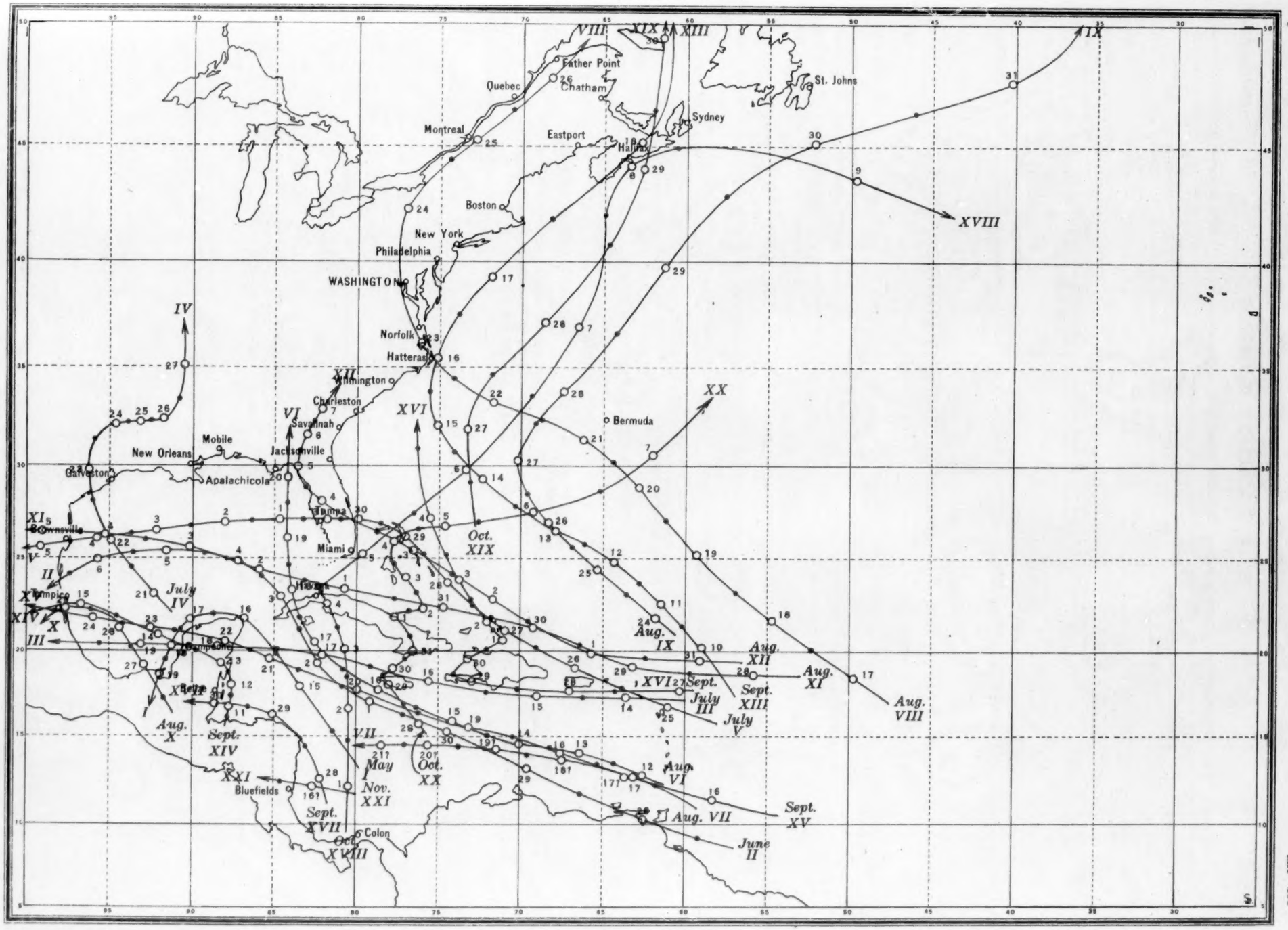
[2] Well developed when first appeared in field of observation.

Paths of Hurricanes and Other Tropical Storms, 1933
(Approximate position at each observation hour)
(Plotted by Arthur J. Haidle)

Paths of Hurricanes and Other Tropical Storms, 1933

(Approximate position at each observation hour)

(Plotted by Arthur J. Haidle)



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Synopsis of tropical storms of 1933. (Number of storm in table corresponds with number of track on accompanying chart)—Continued.

Storm	Date	Place where first reported	Coast lines crossed	Maximum wind velocity reported	Lowest barometer reported	Place of dissipation	Intensity	Remarks
	1933			*Mi. per hr.*	*Inches*			
6	Aug. 12, 20	Near Barbados	None			Northeastern Gulf of Mexico.	Very minor disturbance.	Heavy floods in eastern Jamaica.
7	Aug. 16–21	Windward Islands.	do			Western Caribbean.	Very weak disturbance.	
8	Aug. 17–26	Quite some distance east of Windward Islands.[3]	Cape Hatteras, N.C., and turned northward through Middle and North Atlantic States.	Cape Henry, 66 NE, Hurricane winds over ocean area.	Steamship *Antiochia* 27.76, Cape Hatteras 28.67.	Near mouth of St. Lawrence.	Hurricane	One of worst storms in history of Middle Atlantic coast.
9	Aug. 23, Sept. 24	Several hundred miles northeast of St. Thomas.	None			Greenland	Doubtful but probably not of hurricane intensity.	
10	Aug. 27–29	Southwestern Gulf of Mexico.[1]	Mexico near Tampico			Interior of Mexico	Minor disturbance.	
11	Aug. 28, Sept. 5	Short distance northeast of Windward Islands.	Texas and Mexico almost directly over Brownsville, Tex.	90 NW* Brownsville	28.02 Brownsville	do	Hurricane	Great damage, Rio Grande Valley.
12	Aug. 31, Sept. 7	Northeast of Antigua.	Florida near Jupiter Inlet	125* Jupiter	27.98 Jupiter	Georgia	do	
13	Sept. 10–21	East of Leeward Islands.[3]	Barely touched North Carolina coast line at Cape Hatteras.	125* New Bern, N.C. 76* Hatteras.	27.96 steamship *Washington* 28.25 Hatteras.	Off east coast of Greenland.	do	
14	Sept. 10–15	Extreme western Caribbean.[1]	Yucatan Peninsula north of Payo Obispo and over Tampico, Mexico.	Hurricane winds	28.34 Tampico	Interior of Mexico	do	
15	Sept. 16–24	Western Caribbean.[2]	Yucatan Peninsula south of Cozumel and later a short distance south of Tampico.	do	Steamship *Virginia*, 27.44.	do	do	Great damage around Tampico.
16	Sept. 27, Oct. 4	Near St. Martin	None			Northeast of Bahamas.	Minor disturbance.	
17	Sept. 28–30	Northwest of Isthmus of Panama[1]	British Honduras south of Belize.			British Honduras	Very weak disturbance.	
18	Oct. 1–9	Western Caribbean.[1]	Western Cuba	Steamship *Kaia Kindsen* in Bahamas 150.*	Steamship *Kaia Kindsen*, 28.31.	Merged with another storm off British Isles.	Hurricane	
19	Oct. 26–30	Some distance northeast of Bahamas.	None	Hurricane winds	Steamship *Phoebus* 28.26.	Labrador	do	
20	Oct. 28, Nov. 7	South of Jamaica[1]	Western Jamaica, eastern Cuba.	Steamship *E. W. Sinclair*, 50 NE.	Santiago, 29.58	Southeast of Bermuda.	Probably not of hurricane intensity.	
21	Oct. 16	Southwest Caribbean.[1]	Nicaragua near Bluefields	Bluefields 36 SW.	Bluefields, 29.40	Interior of Nicaragua	Doubtful	

*Estimated.
[1] Approximate place of origin.
[2] Well developed when first appeared in field observation.
[3] Probably originated near the Cape Verde Islands on Aug. 13.

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C. FITZHUGH TALMAN, in Charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING DECEMBER 1933

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1932 REVIEW, page 26.

Beginning with this issue weekly means of solar radiation (direct + diffuse) received on a horizontal surface at Mount Washington, N.H. (lat. 44°16′15″ N., long. 71°18′13″ W., elevation 1,911 meters) will be regularly included in table 2 through the courtesy of the Blue Hill Meteorological Observatory of Harvard University.[1] It may be that complete records of solar radiation at Mount Washington will be difficult to obtain; for example the average wind velocity at that station for December last was 59 m.p.h., while the average temperature was 9.9 ° F., and on December 29 the temperature dropped to 46.2° below zero. The average wind velocity on Christmas Day was 115 m.p.h. With such climatic conditions it is easy to understand the difficulties of keeping in continuous operation a thermoelectric receiver and its recorder.

We regret that the completion of solar radiation studies at Gainesville, Fla., prevents the continuation of the publication of solar data from that station. Much credit is due to Mr. Fred H. Hull of the University of Florida for his efforts in keeping this station in operation until the end of December 1933 in order to complete for us the year's record.

Table 1 shows that solar radiation intensities averaged close to normal for December at all three stations for which normals have been computed.

Table 2 shows an excess in the total solar and sky radiation received on a horizontal surface at Twin Falls, Gainesville, and Miami, and a deficiency at all other stations for which we have normals. A marked excess of radiation for the year was received at all stations with the exception of Madison, Pittsburgh, and Miami.

Turbidity measurements were obtained on the 1st, and 7th only and although these were the clearest days of the month, the readings indicate considerable turbulence.

Polarization measurements obtained on four days at Washington give a mean of 60 percent, with a maximum of 62 percent on the 11th. At Madison, measurements on two days give a mean of 72 percent with a maximum of 74 percent on the 6th. Snow-covered ground prevented further readings at this latter station. The mean value at Washington is slightly higher than normal for December; the other three readings are close to normal for the month.

[1] This table was compiled by Dr. B. Haurwitz of Blue Hill Observatory from observations obtained by the Mount Washington Observatory with Eppley pyrheiometer and Engelhard recording microammeter.

TABLE 1.—*Solar radiation intensities during December 1933*

[Gram-calories per minute per square centimeter of normal surface]

Date	Sun's zenith distance									
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A.M.					P.M.				
	e.	5.0	4.0	3.0	2.0	1.0[1]	2.0	3.0	4.0	5.0	e.
	mm	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*mm*
WASHINGTON, D.C.											
Dec. 1				1.04	1.19						
Dec. 7			0.93	1.16							
Dec. 11							1.28	1.02	0.78		
Dec. 27			1.08	1.17	1.44			1.20			
Means			(1.00)	1.12	1.32		(1.28)	(1.11)	(.78)		
Departures			+.09	+.07	+.09		−.04	+.07	−.13		
MADISON, WIS.											
Dec. 6		0.99	1.03	1.26	1.37						
Dec. 18		.86	.96	1.21	1.40			1.20			
Dec. 26				1.30							
Dec. 28				1.35							
Means		(.92)	(1.00)	1.28	(1.38)			(1.20)			
Departures		−.04	−.09	+.07	+.02			−.03			
LINCOLN, NEBR.											
Dec. 5									1.10	1.02	
Dec. 7				1.10	1.35			1.21	1.09	0.91	
Dec. 8		1.06	1.16	1.30				1.17	1.07	.99	
Dec. 15		.84	1.08	1.27	1.38				.97	.90	
Dec. 16		.76	.92	1.13	1.32			1.24	1.08	.95	
Dec. 18		1.07	1.20	1.38				1.29	1.16	1.04	
Dec. 22								1.17	1.04	.91	
Dec. 23								1.15			
Dec. 26				1.36							
Dec. 27		.85	.97	1.18				1.06	.92	.70	
Means		.92	1.07	1.25	(1.35)			1.18	1.05	.93	
Departures		−.01	+.01	+.02	−.03			−.02	−.02	−.03	
BLUE HILL, MASS.											
Dec. 2	3.4							1.02	0.87	0.76	3.0
Dec. 7	3.3			1.17	1.29		1.27				3.2
Dec. 12	.7			1.36	1.45						.7
Dec. 14	2.0						1.15	.99	.84		1.4
Dec. 16	4.0						1.31	1.04	.85	.72	4.5
Dec. 18	4.6						1.32	1.08	.89		3.3
Dec. 28	1.0						1.38	1.18	1.02	.89	1.0
Means				1.26	1.37		1.29	1.06	.89	.79	

[1] Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Gram calories per square centimeter															
	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Gainesville	Miami	New Orleans	Riverside	Blue Hill	Mount Washington
1933	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*	*cal*
Dec. 3	148	82	202	77	47	207	104	11	157	303	227	322	240	259	66	90
Dec. 10	107	92	140	70	101	160	69	4	124	246	268	335	226	224	127	136
Dec. 17	117	107	208	89	73	160	65	3	153	315	276	302	236	277	120	95
Dec. 24[1]	166	114	152	69	145	83	82	6	136	175	218	286	152	210	147	64
	Departures from weekly normals															
Dec. 3	−12	−36	+24	−11	−49	+17	+20		+39	−2	+12	+23				
Dec. 10	−34	−21	−28	−13	+10	−12	−2		+22	−57	+64	+39				
Dec. 17	−31	−14	+25	+7	−20	+7	−6		+52	+17	+88	+19				
Dec. 24	+18	−9	−32	−15	+48	−57	−2		+15	−96	−31	+4				
	Accumulated departures at the end of year															
	+6,409	−1,976	+5,687	+14,566	+9,855	+10,338	−1,710		+3,431	+8,199		−4,155				
	Percentage departures at end of year															
	+5.2	−1.7	+4.2	+12.3	+10.0	+6.3	−1.7		+2.4	+6.4		−2.6				

[1] 8-day means.

TABLE 3.—*Solar radiation measurements, and determinations of atmospheric turbidity factor, β, Washington, D.C., December 1933*

[Values in italics have been interpolated]

Date and solar hour angle	Solar altitude, h.	Air mass, m.	I_m	I_y	I_r	β	Blueness of sky	Note: Skylight polarization, P., clouds, etc.
Dec. 1								
			gr. cal	*gr. cal*	*gr. cal*			
2:31a	19-40	2.95	1.041	*0.803*	0.667	0.080	5	
2:25a	20-25	2.85	1.096	.806	*.669*	.065		
0:29a	28-53	2.06	1.198	.881	*.725*	.088		
0:24a	29-01	2.06	1.181	.885	.727	.095		P=56.6
Dec. 7								
2:46a	18-08	3.19	1.116	.857	.716	.120	6	
2:39a	18-56	3.06	1.158	.858	*.790*	.105		P=60.4

TABLE 4.—*Solar radiation measurements obtained at Blue Hill Meteorological Observatory of Harvard University during December 1933*

I_m=intensity in the whole spectrum; I_y=intensity transmitted by yellow glass screen OG_1; I_r=intensity transmitted by red glass screen RG_2]

Date and solar hour angle	Solar altitude, h.	Air mass, m.	I_m	I_y	I_r	Sky conditions. (Clouds, haze (hz), visibility (v), wind, etc.). International symbols are employed for wind direction and velocity, and kind of clouds.
Dec. 2	° ′		*gr. cal*	*gr. cal*	*gr. cal*	
3:29, p.m.	9 44	5.75	0.720	0.580	0.490	2 Ci; hz; v 8; WNW-3.
Dec. 7						
0:58, a.m.	23 55	2.46	1.224	.909	.747	1 Acu, few Frcu; dns hz; v 7; NW-7.
0:42, p.m.	24 26	2.41	1.210	.873	.706	2 Ci, 1 Cu; solar corona; v 7; NW 7-8.
Dec. 14						
1:30, p.m.	21 20	2.74	1.026	.770	.621	No clouds; v 6; NNE-1.
2:44, p.m.	14 26	3.97	.842	.634	.522	
Dec. 16						
1:14, p.m.	22 16	2.62	1.135	.854	.676	1 Ci; v 6; WSW-3.
2:31, p.m.	15 46	3.63	.908	.692	.588	1 Ci; v 6; W-3.
Dec. 28						
2:40, p.m.	14 47	3.86	1.004	.793	.664	Few Frcu; lt hz; v 8; WSW-5.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent U.S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1933	h. m.	°	°	°			
Dec. 1 (Naval Observatory)	12 15		No spots				
Dec. 2 (Naval Observatory)	12 16		No spots				
Dec. 4 (Naval Observatory)	13 10		No spots				
Dec. 5 (Mount Wilson)			No spots				
Dec. 6 (Mount Wilson)			No spots				
Dec. 7 (Naval Observatory)	12 29		No spots				
Dec. 8 (Naval Observatory)	11 9		No spots				
Dec. 9 (Mount Wilson)			No spots				
Dec. 10 (Naval Observatory)	11 46		No spots				
Dec. 11 (Naval Observatory)	11 27	−19.0	186.7	+2.0	28	28	
Dec. 12 (Harvard Observatory)			No spots				
Dec. 13 (Harvard Observatory)			No spots				
Dec. 14 (Naval Observatory)	13 20		No spots				
Dec. 15 (Mount Wilson)			No spots				
Dec. 16 (Mount Wilson)			No spots				
Dec. 17 (Mount Wilson)			No spots				
Dec. 18 (Naval Observatory)	13 3		No spots				
Dec. 19 (Mount Wilson)			No spots				
Dec. 20 (Mount Wilson)			No spots				
Dec. 21 (Naval Observatory)	11 46		No spots				
Dec. 22 (Naval Observatory)	10 40		No spots				
Dec. 23 (Naval Observatory)	10 52		No spots				
Dec. 24 (Naval Observatory)	13 20		No spots				
Dec. 25 (Naval Observatory)	11 10		No spots				
Dec. 26 (Mount Wilson)			No spots				
Dec. 27 (Naval Observatory)	10 29		No spots				
Dec. 28 (Naval Observatory)	14 39		No spots				
Dec. 29 (Naval Observatory)	15 3		No spots				
Mean daily area for December							1

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR DECEMBER 1933

[Dependent alone on observations at Zurich and its station at Arosa]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgenössische Sternwarte, Zurich, Switzerland]

December 1933	Relative numbers	December 1933	Relative numbers	December 1933	Relative numbers
1	0	11	*Mc* 9	21	0
2	0	12	0	22	0
3	0	13	0	23	0
4	0	14	0	24	0
5	0	15		25	0
6	0	16	0	26	0
7	0	17	0	27	0
8	0	18	0	28	0
9	0	19	0	29	0
10	0	20	0	30	0
				31	0

Mean: 30 days = 0.3.

c=New formation of a center of activity: *M*, in the central zone.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

[Aerological Division, L. T. Samuels temporarily in charge]

The outstanding features of the average free-air temperatures for December as shown in table 1 are the large positive departures at Dallas and Omaha, and the negative departures at Pembina. This steepening of the normal south-north latitudinal temperature gradient resulted in higher free-air resultant wind velocities than normal for the month as was evident at a number of stations (table 2). Resultant directions were close to normal, except along the Pacific coast, where a preponderance of westerly winds prevailed as compared to the normal northerly components.

Free-air relative humidity departures were mostly small and insignificant except at Boston where large positive departures occurred.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during December 1933*

TEMPERATURE (° C.)

Altitude (meters) m.s.l.	Boston, Mass.[1] (6 m)		Cleveland, Ohio [2] (246 m)		Dallas, Tex.[3] (146 m)		Omaha, Nebr.[4] (300 m)		Pembina, N.Dak.[5] (243 m)		San Diego, Calif.[6] (9 m)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	−2.1	(7)	−0.7	(7)	7.8	(7)	−3.7	(7)	−20.4	(7)	11.0	−2.4
500	−2.6	(7)	−0.5	(7)	11.7	(7)	−2.2	(7)	−19.3	(7)	12.9	−0.2
1,000	−3.4	−2.0	−1.3	+3.0	13.5	+6.8	0.4	+3.3	−16.1	(7)	13.5	+1.0
1,500	−4.1	−2.9	−1.9	+2.5	12.5	+6.5	1.8	+4.4	−12.1	−3.8		
2,000	−5.1	−2.2	−2.3	+3.3	10.6	+6.1	1.2	+5.2	−12.2	−2.7	9.7	+1.0
2,500	−6.7	−2.3	−3.2	+4.2	8.1	+5.6	−0.8	+5.5	−13.2	−1.7		
3,000	−8.5	−1.4	−4.8	+4.8	5.5	+5.2	−3.3	+5.4	−15.4	−1.3	4.8	+0.8
4,000	−12.3	+0.2	−9.9	+5.6	−0.4	+4.6	−9.4	+4.5	−20.9	−0.8	−1.5	+0.5
5,000	−17.6	+0.5	−15.8	+5.6	−7.7	+2.8	−16.2	+3.2	−27.8	−1.2		

RELATIVE HUMIDITY (PERCENT)

Surface	75	(7)	81	(7)	82	(7)	80	(7)	84	(7)	73	+11
500	72	(7)	74	(7)	66	(7)	73	(7)	73	(7)	59	+4
1,000	69	+12	72	+5	57	+1	60	−3	68	(7)	45	0
1,500	65	+14	61	+4	50	+3	50	−7	65	+6		
2,000	59	+13	53	+1	43	+3	46	−9	63	+6	29	−2
2,500	57	+13	48	−3	35	−2	47	−9	58	+1		
3,000	58	+16	49	−1	31	−3	46	−11	57	0	22	−2
4,000	61	+20	50	−2	24	−10	47	−10	57	0	19	−1
5,000	52	+12	48	−1	23	−10	47	−10	54	+3		

Times of observations: Weather Bureau, 5 a.m.; Navy, 7 a.m.; and M.I.T., 8 a.m., E.S.T.

[1] Observations made by Massachusetts Institute of Technology; departures based on normals obtained from kite observations made at Blue Hill Meteorological Observatory.
[2] Temperature departures based on normals determined by extrapolating latitudinally those of Royal Center, Ind., and Due West, S.C. Humidity departures based on normals of Royal Center, Ind.
[3] Temperature departures based on normals determined by interpolating latitudinally those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.
[4] Temperature and humidity departures based on normals of Drexel, Nebr.
[5] Temperature departures based on normals determined by extrapolating latitudinally those of Ellendale, N.Dak., and Drexel, Nebr. Humidity departures based on normals of Ellendale, N.Dak.
[6] Naval air station.
[7] Departures for the surface and for these levels omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a.m. (E.S.T.) during December 1933*

[Winds from N=360°, E=90°, etc.]

Altitude (meters) m.s.l.	Albuquerque, N. Mex. (1,554 meters)		Atlanta, Ga. (309 meters)		Bismarck, N.Dak. (518 meters)		Brownsville, Tex. (7 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (192 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	351	1.4	301	1.1	60	1.0	192	1.1	212	1.6	265	6.0	284	1.1	220	2.4	250	0.4	226	2.0	273	0.8	48	3.0
500			268	3.6			182	9.2	237	4.0			273	3.0	245	5.8	233	5.3			251	3.2	87	5.8
1,000			270	7.2	289	5.9	194	7.3	284	7.5			288	6.7	270	9.0	260	7.9	238	5.2	258	3.6	111	4.5
1,500			267	8.1	280	10.3	190	3.8	285	11.0			287	9.5	267	11.8	259	7.9	260	12.0	273	5.0	95	2.4
2,000	312	3.6	266	8.4	278	10.9	244	1.9	286	13.2	268	9.6	292	13.7	270	14.6	268	7.1	271	15.3	270	5.9	40	.6
2,500	307	6.5	281	6.9	283	12.5	271	2.8	288	14.9	277	13.9	276	14.9	270	18.2	263	8.1	280	15.5	270	6.2	327	1.9
3,000	305	9.3	281	10.2			268	4.2	286	17.8	285	16.1			281	19.2	269	9.2	284	13.7	282	7.1	336	1.5
4,000	286	12.6	282	9.8			265	4.6			285	15.9					284	11.4					249	.6
5,000	285	12.5					265	5.9															276	2.6

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a.m. (E.S.T.) during December 1933*—Continued

Altitude (meters) m.s.l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (83 meters)		New Orleans, La. (1 meter)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Phoenix, Ariz. (338 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D.C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	338	2.1	142	1.2	227	0.2	52	0.3	120	1.5	273	0.6	104	0.6	96	2.3	147	3.1	348	1.0	180	2.5	311	1.4
500	334	1.6	154	1.9	234	5.2	227	3.6	168	1.9	233	1.1	218	1.9	96	2.6	------	------	323	2.4	207	11.2	274	6.5
1,000	100	.5	179	4.4	259	5.1	251	5.8	201	1.8	252	4.1	251	4.4	69	1.6	------	------	314	6.6	217	12.8	276	9.2
1,500	212	1.2	219	7.4	267	7.4	252	6.3	238	2.8	255	6.2	265	6.4	303	.5	165	5.2	304	9.8	234	11.8	290	15.0
2,000	265	2.7	231	12.0	258	8.7	276	5.6	256	3.3	255	8.2	273	9.9	286	1.7	195	5.3	293	13.5	240	13.8	284	15.2
2,500	258	3.7	237	14.3	276	9.2	257	5.9	262	4.8	255	9.7	277	12.2	282	3.1	250	5.0	296	15.9	248	12.9	265	12.9
3,000	261	2.9	231	16.2	272	7.4	272	7.3	278	6.2	253	9.5	283	13.2	280	4.0	264	8.6	------	------	------	------	------	------
4,000	252	2.8	265	14.0	------	------	------	------	256	8.7	273	11.4	279	11.5	268	7.5	288	11.2	------	------	------	------	------	------
5,000	------	------	------	------	------	------	------	------	265	7.9	------	------	------	------	287	6.3	291	18.0	------	------	------	------	------	------

AEROLOGICAL OBSERVATIONS FOR THE YEAR 1933

By L. T. SAMUELS

[Aerological Division, L. T. Samuels, temporarily in charge]

Mean free-air temperatures for the year at the stations shown in table 1 were mostly above normal with the largest departures occurring at Dallas and Omaha. Free-air relative humidities averaged above normal except at Omaha and Norfolk where they were below normal.

Kite observations were completely discontinued by the Weather Bureau upon the closing of the Ellendale, N.Dak., station in June 1933, and a new airplane-observation station was established in July at Pembina, N. Dak. Owing to decreased appropriations, the airplane-observation work was discontinued at Atlanta and Chicago on June 30. Airplane observations were made on all but 2 days during the year at Dallas, on all but 12 days at Cleveland, and on all but 14 at Omaha. The average height reached in these observations was 5 km.

During the International Polar Year, which ended August 31, 1933, a total of 234 sounding-balloon observations were made at 3 stations. The number of these instruments found and returned was 197 or 84 percent. In practically all cases the observations extended into the stratosphere.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during 1933*

TEMPERATURE (° C.)

Altitude (meters) m.s.l.	Cleveland, Ohio (246 meters) [1]		Dallas, Tex. (146 meters) [2]		Norfolk, Va. (3 meters) [3]		Omaha, Nebr. (300 meters) [4]		Pensacola, Fla. (2 meters) [3]		San Diego, Calif. (9 meters) [3]		Washington, D.C. (2 meters) [3]	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	8.0	[5]	15.4	[5]	13.7	−0.7	7.7	[5]	18.8	+0.5	15.4	−2.0	11.0	−1.3
500	9.2	[5]	17.5	[5]	12.9	−.6	8.8	[5]	18.1	+.8	14.3	−1.1	11.5	+.4
1,000	7.5	+1.3	16.7	+2.7	11.2	−.3	10.0	+2.0	16.2	+.9	15.1	−.6	10.6	+1.2
1,500	5.4	+1.1	14.9	+2.7	------	------	8.8	+2.2	------	------	------	------	------	------
2,000	3.3	+1.1	12.6	+2.6	6.5	−.4	6.7	+2.3	11.3	+.5	12.8	+.3	6.2	+.9
2,500	1.2	+1.3	9.9	+2.4	------	------	4.1	+2.3	------	------	------	------	------	------
3,000	−1.1	+1.5	7.1	+2.2	1.8	−.4	1.2	+2.2	5.7	−.1	7.3	0.0	1.9	+.9
4,000	−6.6	+1.3	1.3	+2.0	−4.7	−1.5	−5.2	+1.6	−.1	−.1	.6	−.1	−3.3	+1.1
5,000	−12.8	+1.0	−5.1	+1.2	------	------	−11.8	+1.0	−6.5	−.1	−6.7	−.6	------	------

RELATIVE HUMIDITY (PERCENT)

Surface	79	[5]	81	[5]	71	−1	78	[5]	81	0	72	+4	76	+6
500	70	[5]	68	[5]	63	−1	70	[5]	75	+1	71	+3	66	+3
1,000	67	+2	61	−1	58	−2	57	−4	70	+2	55	+3	60	+1
1,500	64	+3	56	+2	------	------	52	−5	------	------	------	------	------	------
2,000	59	+2	52	+4	52	−2	48	−7	63	+4	35	+1	58	+2
2,500	53	0	48	+3	------	------	46	−9	------	------	------	------	------	------
3,000	51	0	45	+3	45	−2	45	−10	55	+4	29	+3	52	+3
4,000	49	+2	41	+2	53	+8	43	−10	48	+3	27	+3	46	+1
5,000	46	+1	39	+4	------	------	41	−11	44	+3	23	+1	------	------

Times of observations: Weather Bureau, 5 a.m.; Navy, 7 a.m., E.S.T.

[1] Temperature departures based on normals determined by extrapolating latitudinally those of Royal Center, Ind., and Due West, S.C. Humidity departures based on normals of Royal Center, Ind.

[2] Temperature departures based on normals determined by interpolating latitudinally those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.

[3] Naval air stations.

[4] Temperature and humidity departures based on normals of Drexel, Nebr.

[5] Surface and 500-meter level departures omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

RIVERS AND FLOODS

By MONTROSE W. HAYES

[In charge River and Flood Division]

During December 1933 there were floods in the Green River of Kentucky and in the Columbia Basin. A discussion of these overflows, together with a statement of flood losses during the year, will appear in a later issue of the REVIEW.

THE WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

By WILLIS E. HURD

[By the Marine Division, Willis E. Hurd Acting in Charge]

NORTH ATLANTIC OCEAN

The pressure situation.—The center of low pressure over the North Atlantic Ocean during December 1933 occurred in the northwestern portion. Julianehaab, Greenland, had an average pressure of 29.27 inches. The lowest pressure reading of the month, 28.40 inches, occurred there on the 26th. The daily centers of activity were for the greater part confined to northern and western waters, except that during the last decade cyclonic conditions spread eastward and during the last few days of the month overlay western European waters. At sea the lowest pressure recorded was 28.54 inches, read on the Swedish motorship *Blankaholm*, in 49°17′ N., 47°58′ W., on December 1. A reading of 28.55 inches was made on the Dutch steamer *Laertes* in 47°50′ N., 36°00′ W., on the 20th.

Anticyclonic conditions prevailed for the most part over the lower temperate waters, but the crest of high pressure lay in the neighborhood of the Azores (average pressure at Horta, 30.21 inches). The highest barometer reading along the North Atlantic coast during the month was 30.98 inches, in southwestern Norway, on the 3d.

Average pressures along the coasts as a rule were abnormally high, but the abnormalities were slight, as noted in table 1, except over northeastern waters, where they were considerable; that at Lerwick showing a plus departure of 0.43 inch. Lisbon is the only station shown in the table that had a minus departure.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, December 1933*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.27		30.08	11	28.40	26
Reykjavik, Iceland	29.73	+0.26	30.44	5	29.07	1
Lerwick, Shetland Islands	30.15	+.43	30.84	4	29.40	30
Valencia, Ireland	30.12	+.18	30.57	3	29.15	28
Lisbon, Portugal	30.04	−.07	30.58	23	29.57	14
Madeira	30.11	+.02	30.49	24	29.55	11
Horta, Azores	30.21	+.07	30.56	26, 27	29.80	20
Belle Isle, Newfoundland	29.77	+.07	30.24	16	28.96	22
Halifax, Nova Scotia	29.97	+.02	30.54	15, 26	29.10	27
Nantucket	30.05	.00	30.72	29	29.34	21
Hatteras	30.17	+.04	30.72	29	29.74	6
Bermuda	30.14	+.02	30.38	16, 31	29.66	10
Turks Island	30.07	+.04	30.18	18	29.94	9
Key West	30.13	+.05	30.27	31	29.89	7
New Orleans	30.15	+.02	30.47	29	29.71	6
Cape Gracias, Nicaragua	29.94	+.02	30.00	11, 12	29.88	6

NOTE.—All data based on a.m. observations only, with departures, compiled from best available normals related to time of observations, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—The fact that approximately 140 gale reports were furnished for December 1933 from the North Atlantic by seamen observers, is indicative of the considerable degree of storminess prevailing in these waters during the month. Major wind forces of 11 to 12 were reported as occurring on at least 9 days—the 1st, 3d, 5th, 10th, 11th, 12th, 19th, 20th, and 24th, while gales equaling at least force 10 were experienced on several other days, mostly along the northern steamer routes.

At the beginning of the month a deep cyclone lay east of Newfoundland, whence it moved gradually northward toward Greenland. During the 1st to 5th it affected a great portion of the northern routes, causing gales of force 8 to 12 from the American coast to the thirtieth meridian. On the 6th to 8th, the quietest period of the month, the LOW spread eastward and dissipated.

On the 4th a continental depression entered the ocean from the Virginia Capes, and on the 5th was causing locally fresh to strong gales between Nova Scotia and Bermuda.

On the 9th another cyclone appeared off the east coast of the United States, with fresh to strong gales between 30° and 40° N., to the westward of the 70th meridian, attending its development. The gale field on the 10th spread eastward as far as the 60th parallel and north to Newfoundland, where it continued through the 11th and 12th, with maximum wind forces of 11 and 12 experienced on all 3 days in the neighborhood of 38°–42° N., 55° to 63° W., and gales of lower velocity throughout Newfoundland waters.

Up to the 12th and 13th gales were of rare occurrence in European waters, but on these days winds of force 8 to 9 occurred from the English Channel southward into the Bay of Biscay and westward to the 15th meridian. Scattered gales of similar force were experienced in the same vicinity during the last few days of December, in connection with the first important cyclonic development of the month in this part of the eastern Atlantic.

From the 15th to 20th gales continued in the central Atlantic. The peak of extent and intensity occurred on the 19th, during which winds of force 9 to 11 were encountered over a considerable region between Bermuda and the Azores, and on the 20th, with winds of similar force—and in one instance of force 12—at some distance north of the Azores.

During the last decade gales were infrequent along the American coast, and the few reported included a strong gale near Cape Cod on the 26th, and fresh gales near Cape Hatteras and in the Florida Straits on the 29th and 31st, respectively. The highest velocity experienced for the period was of force 11, on the 24th, near 49½° N., 37° W.

On the 27th a cyclone centered near Labrador was productive of severe weather from Newfoundland waters southward to the fortieth parallel, and eastward to mid-ocean. The effect of this LOW, existing simultaneously with a storm center over the extreme eastern Atlantic, was that on the last 5 days of the month, gales occurred along the northern routes from the 60th meridian eastward to the European coast.

Fog.—Fog was somewhat more frequent along the American coast this month than in November. It occurred on 6 days along the New England coast; on 5 days thence southward to Cape Hatteras; and on 3 days in the northwestern part of the Gulf of Mexico. Over and near the Gulf Stream from 35° N. to the Grand Banks of Newfoundland fog was observed on 2 to 6 days in various 5° squares. East of longitude 45° W. fog was scattered and infrequent, except in the English Channel, where it was reported on 4 days.

OCEAN GALES AND STORMS, DECEMBER 1933

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Frederick VIII, Dan. S.S.	Oslo	New York	49 35 N	47 10 W	Nov. 30	10a, Dec 1	Dec. 1	28.78	SSE	SW, 9	W	SW, 9	SSE-SW.
City of Bagdad, Br. S.S.	Gibraltar	Havre	42 52 N	9 28 W	Dec. 2	Noon, 1	Dec. 3	29.97	NNW	W, 4	E	E, 9	
City of Havre, Am. S.S.	Havre	Norfolk	45 40 N	42 26 W	Dec. 1	do	Dec. 1	29.32	SSW	SW, 10	W	SW, 10	SW-WSW.
Blankaholm, Swed. M.S.	Gothenburg	Habana	49 17 N	47 58 W	do	do	do	28.54	SW	WSW, 9	W	WSW, 11	None.
Black Gull, Am. S.S.	New York	Antwerp	41 12 N	63 50 W	do	2p., 1	Dec. 2	29.66	NW	NW, 8	NW	NNW, 9	WNW-NW.
Bremen, Ger. S.S.	Bremerhaven	New York	48 30 N	35 12 W	do	8p., 1	do	29.17	SW	SSW, 10	WSW	SSW, 10	
Spidoleine, Belg. M.S.	Rouen	do	43 01 N	50 25 W	Dec. 2	1p., 2	do	28.97	WNW	NNW, 10	NW	NNW, 10	W N W - N W - NNW.
Pres. Harding, Am. S.S.	New York	Hamburg	43 54 N	46 00 W	do	9p., 2	Dec. 3	28.99	NW	NW, 7	W	NW, 10	W-NW.
Elsa, Nor. S.S.	Texas City	Dunkerque	46 40 N	37 26 W	do	, 2	do	29.46	S	S, 9	S	S, 11	Steady.
McKeesport, Am. S.S.	Havre	New York	49 08 N	41 00 W	Dec. 3	2a., 3	Dec. 4	28.71	NNW	NNE, 7	N	WNW, 10	
Georgia, Dan. S.S.	Newcastle-on-Tyne.	Norfolk	53 30 N	37 10 W	Dec. 1	6a., 3	Dec. 3	28.58	SSE	SSE, 12	NW	S, 12	SSE-S-SW.
Solana, Am. S.S.	Houston	Fall River	39 20 N	72 00 W	Dec. 4	6p., 4	Dec. 5	29.82	N	NNE, 9	NE	NNE, 9	NNE.
Georgia, Dan. S.S.	Newcastle-on-Tyne.	Norfolk	51 15 N	42 35 W	Dec. 5	2a., 5	Dec. 6	28.74	NW	NW, 11	WNW	NW, 11	None.
St. Louis, Ger. M.S.	Cobh	New York	51 12 N	32 00 W	Dec. 4	2p., 5	do	29.07	SE	WSW, 10	W	SSE, 10	6 points.
Borinquen, Am. S.S.	San Juan	do	32 40 N	70 56 W	Dec. 9	8p., 9	Dec. 10	29.65	SW	SW, —	NW	NW, 10	SW-NW.
Ida Z. O., Ital. S.S.	Seville	Philadelphia	33 38 N	65 20 W	Dec. 10	10a., 10	Dec. 11	29.66	W	W, 7	SW	SW, 9	
Excalibur, Am. S.S.	Malaga	Boston	42 35 N	65 35 W	do	1p., 10	do	28.93	NNW	NNW, 10	NW	NNW, 10	E-NNW.
Jeff Davis, Am. M.S.	Gibraltar	New York	34 55 N	57 20 W	do	2p., 10	Dec. 13	29.64	S	S, 8	WNW	SW, 11	S-SW.
Georgia, Dan. S.S.	Newcastle-on-Tyne.	Norfolk	42 30 N	62 36 W	do	4p., 10	Dec. 12	28.94	SW	SW, 9	NW	N, 11	SW-WSW.
Kungsholm, Swed. M.S.	Gothenburg	New York	44 06 N	58 18 W	Dec. 11	10p., 10	do	29.05	WSW	SE, 5	WNW	WNW, 11	S-SE-SW.
D. G. Scofield, Am. S.S.	Fall River	Cristobal	37 26 N	71 55 W	do	8a., 11	Dec. 11	29.55	SW	SW, 8	WNW	W, 10	SW-W.
Conte di Savoia, It. S.S.	Gibraltar	New York	38 05 N	55 00 W	do	11p., 11	Dec. 13	29.52	WSW	WNW, 12	WSW	WSW, 12	Steady.
Breedyk, Du. S.S.	Rotterdam	do	42 07 N	57 57 W	do	2a., 12	do	28.97	SW	SW, 10	WNW	WNW, 10	SW-NW.
Europa, Ger. S.S.	English Channel.	do	42 43 N	55 57 W	do	4a., 12	Dec. 12	29.09	SE	WSW, 10	WNW	W, 11	WSW-WNW.
Carlsholm, Swed. S.S.	Gothenburg	Baltimore	46 07 N	54 11 W	do	6a., 12	Dec. 14	[3]28.77	SSE	SSW, 12	NNE	SSW, 12	SE-SSW.
Cranford, Am. S.S.	New Orleans	London	[1]49 28 N	[1]11 39 W	Dec. 12	5p., 13	do	29.71	NW	NE, 8	NE	N, 10	Steady.
Boston City, Br. S.S.	Halifax	Cardiff	48 13 N	46 41 W	Dec. 14	5a., 15	Dec. 16	29.14	SE	SSW, 8	NNW	NNW, 9	S-SSW-W.
Cingalese Prince, Br. M.S.	Gibraltar	Halifax	42 38 N	40 58 W	Dec. 17	4p., 17	Dec. 17	29.46	SW	WSW, 8	WNW	SW, 10	SW-W.
Thurland Castle, Br. M.S.	do	New York	35 26 N	58 25 W	Dec. 18	8p., 18	Dec. 19	29.87	W	W, 8	N	N, 10	WSW-W-WNW.
American Banker, Am. S.S.	New York	London	41 12 N	57 02 W	Dec. 19	11p., 18	do	29.34	NNE	N, 7	N	N, 10	NW-N-NNE.
Samala, Br. S.S.	Jamaica	Havre	38 05 N	51 51 W	do	7a., 19	do	29.25	WSW	NNW, 10	NNW	NNW, 10	WSW-NNW.
Portfield, Br. S.S.	Gibraltar	Portland, Maine.	34 58 N	48 20 W	do	9a., 19	Dec. 20	29.66	WSW	W, 9	NW	W, 10	SW-W-NW.
Exmouth, Am. S.S.	do	New York	35 50 N	43 15 W	Dec. 18	2p., 19	do	29.31	SW	WSW, 10	NW	SW, 11	SW-WSW.
Jomar, Am. S.S.	Galveston	Lisbon	40 42 N	44 21 W	Dec. 19	6p., 19	Dec. 21	28.94	E	NW, 7	W	NW, 10	Steady.
Roma, Ital. S.S.	Gibraltar	New York	37 42 N	46 43 W	do	do	Dec. 19	29.06	SSW	W, 10	NW	W, 11	Do.
Black Tern, Am. S.S.	New York	Antwerp	46 06 N	38 30 W	do	6a., 20	Dec. 20	28.80	NNE	N, 10	NW	NW, 10	NNE-NNW.
Laertes, Du. S.S.	Liverpool	Boston	47 50 N	36 00 W	Dec. 20	1p., 20	Dec. 21	28.55	S	NNW, 10	NNW	NNW, 10	S-NNW.
Spidoleine, Belg. M.S.	Philadelphia	London	47 00 N	28 25 W	Dec. 19	3p., 20	Dec. 20	28.89	SE	S, 11	SW	S, 11	SSE-S-SW.
City of Newport News, Am. S.S.	Havre	Norfolk	47 50 N	28 30 W	do	do	Dec. 21	29.23	S	SSE, 11	SW	SW, 12	None.
City of Joliet, Am. S.S.	Houston	Havre	43 20 N	44 00 W	Dec. 18	4a., 21	do	29.77	E	NW, 8	NW	N, 10	Do.
City of Newport News, Am. S.S.	Havre	Norfolk	45 50 N	31 30 W	Dec. 21	6p., 21	Dec. 22	29.16	SE	NNW, 8	NW	NNW, 10	SE-NNW.
Champlain, Fr. S.S.	do	New York	49 35 N	37 15 W	Dec. 23	11p., 23	Dec. 24	29.18	SSE	W, 8	W	W, 11	
Black Gull, Am. S.S.	Antwerp	do	50 19 N	26 28 W	Dec. 26	6p., 26	Dec. 27	29.55	WSW	W, 8	W	WNW, 10	WSW-W.
Quaker City, Am. S.S.	Halifax	Dundee	[1]49 00 N	[1]41 21 W	Dec. 28	4a., 28	Dec. 29	29.55	WSW	WSW, 8	SW	W, 9	SSE-WSW.
Colombie, Fr. S.S.	Havre	Cristobal	48 20 N	8 40 W	do	5p., 28	do	29.19	WNW	WNW, 9	NNW	NW, 9	
Black Gull, Am. S.S.	Antwerp	New York	48 20 N	43 58 W	Dec. 29	2a., 30	Dec. 31	29.32	S	SSW, 9	WSW	WSW, 9	S-SSW-W.
Minnequa, Am. S.S.	Copenhagen	Philadelphia	57 40 N	24 00 W	do	4p., 30	do	29.06	WNW	SSE, 10	SW	W, 10	SW-SSE-SW.
Gorm, Dan. S.S.	Methil, Scotland.	Portland, Maine.	57 16 N	20 22 W	do	9p., 31	Jan. 1	[3]29.27	WNW	W, 10	WNW	SW, 10	
Mobile City, Am. S.S.	New Orleans	New York	24 38 N	80 32 W	Dec. 31	11p., 31	Dec. 31	30.07	E	ESE, 7	E	E, 8	E-ESE-E.
NORTH PACIFIC OCEAN													
Steel Trader, Am. S.S.	Seattle	Hawaiian Islands.	45 16 N	129 55 W	Dec. 1	Noon, 1	Dec. 1	29.37	S	S, 8	S	S, 8	
Tejon, Am. S.S.	Los Angeles	Portland, Oreg.	42 19 N	124 48 W	Dec. 2	6a., 2	Dec. 2	29.89	S	S, 8	SSW	SSW, 8	SSE-S-SSW.
Shoyo Maru, Jap. S.S.	Estero Bay	Yokohama	31 48 N	154 22 E	do	4p., 2	do	[3]29.45	S	S, 8	S	S, 8	SSE-S-SW.
Tejon, Am. S.S.	Portland, Oreg.	San Francisco.	[1]46 10 N	[1]123 55 W	Dec. 5	3p., 5	Dec. 5	29.71	S	SSE, 12	S	SSE, 12	S-SSE.
Mobile City, Am. S.S.	Kahului, Hawaii.	Balboa	11 24 N	146 09 W	Dec. 4	4p., 5	Dec. 7	29.88	E	E, 8	E	E, 9	None.
Golden Star, Am. S.S.	Philippine Islands.	San Francisco.	36 23 N	159 26 E	Dec. 7	4a., 8	Dec. 8	29.49	W	WNW, 9	NW	WNW, 9	WSW-WNW
Golden Tide, Am. S.S.	San Francisco.	Yokohama	32 15 N	156 52 W	Dec. 8	Noon, 8	do	29.85	N	N, 9	N	NNE, 9	N-NNE.
Fernhill, Nor. M.S.	Los Angeles	Balboa	14 18 N	96 20 W	Dec. 9	3p., 9	Dec. 11	29.84	NE	NNE, 8	N	NNE, 9	NE-NNE-N.
Aorangi, Br. M.S.	Victoria	Honolulu	37 29 N	142 24 W	Dec. 11	8a., 10	do	29.38	W	W, 8	NW	WNW, 11	SW-W.
San Diego Maru, Jap. S.S.	Kobe	San Francisco.	43 48 N	143 30 W	do	4p., 10	Dec. 10	28.99	NNE	NE, 4	NE	NE, 8	NE-NNE.
Juyo Maru, Jap. S.S.	Muroran, Japan.	Portland, Oreg.	47 50 N	144 15 W	Dec. 9	8p, 10	Dec. 12	29.67	NE	NE, 10	NNW	NE, 10	NE.
Shoyo Maru, Jap. S.S.	Yokohama	Los Angeles	36 42 N	153 24 E	Dec. 10	Mdt., 10	Dec. 11	[3]29.18	S	S, 8	S	S, 9	S-WSW.
Pulpit Point, Br. S.S.	do	do	38 15 N	152 00 E	do	do	do	28.94	S	SSW, 9	W	S, 10	S-SSW-W.
President Cleveland Am. S.S.	do	Victoria	49 05 N	131 57 W	do	8p., 11	do	29.00	ENE	N, 7	NNE	N, 11	NNE-N.
Golden Tide, Am. S.S.	San Francisco.	Yokohama	31 06 N	165 03 W	do	4a., 11	do	29.70	E		ESE	ESE, 9	None.
Ogura Maru, Jap. M.S.	Uraga, Japan	Los Angeles	38 22 N	157 13 E	Dec. 11	8a., 11	do	29.33	S	S, 9	E	S, 9	S-E.
Maunalei, Am. S.S.	Seattle	Honolulu	42 16 N	135 33 W	do	Noon, 11	Dec. 12	29.04	SSW	SW, 8	NW	NW, 9	SW-W-NW.
Teiyo Maru, Jap. M.S.	Estero Bay	Yokohama	36 32 N	136 30 W	do	2p., 11	Dec. 11	29.30	WSW	W	WSW	WSW, 8	WSW-W.
Brandywine, Am. S.S.	Seattle	Los Angeles	42 06 N	124 46 W	do	10p., 11	Dec. 12	29.21	S	S, 8	SSE	S, 10	S-SE.
Fernbrook, Nor. M.S.	Philippine Islands.	do	39 12 N	173 10 W	Dec. 12	8p., 13	Dec. 13	29.68	NE	N, 7	NE	NE, 8	NE-N.

[1] Position approximate.

[3] Uncorrected.

OCEAN GALES AND STORMS, DECEMBER 1933—Continued

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN			° ′	° ′				*Inches*					
Hakutatsu Maru, Jap. S.S.	Kamaishi	Vancouver	49 30 N	131 00 W	Dec. 10	3a., 14	Dec. 12	29.67	NE	NW, 6	N	N, 10	None.
Hiye Maru, Jap.M.S.	Vancouver	Yokohama	47 26 N	163 26 E	Dec. 15	10p., 15	Dec. 16	29.16	ESE	SSE, 9	SW	SE, 9	SE-S.
Yuri Maru, Jap.S.S.	Iloilo	Balboa	31 05 N	142 38 E	Dec. 16	4p., 17	Dec. 18	[1]29.55	S	W, 9	NW	S, 10	10 points.
Michigan, Am.S.S.	Dairen	San Francisco.	41 23 N	169 48 E	do	11p., 16	Dec. 17	28.83	NW	NW, 8	WSW	WSW, 10	NW-W.
Hiye Maru, Jap.M.S.	Vancouver	Yokohama	41 59 N	149 58 E	Dec. 17	6p., 17	do	29.10	SE	S, 8	W	SSE, 9	SSE-S-SW.
California, Ital.S.S.	San Francisco.	Vancouver	43 25 N	125 07 W	do	9p., 17	Dec. 18	29.96	S	SSW, 8	WSW	SSW, 8	S-SSW-SW.
Iwatesan Maru, Jap.S.S.	Yokohama	Los Angeles	46 46 N	170 37 W	Dec. 18	6p., 18	Dec. 20	[1]29.41	E	E, 9	E	E 10	Steady.
Kentucky, Am.S.S.	Philippine Islands.	San Francisco.	38 23 N	166 10 E	Dec. 19	8a., 19	Dec. 19	29.15	NW	NW, 6	NW	NW, 8	None.
Golden Star, Am.S.S.	do	do	43 27 N	143 34 W	do	3p., 19	do	29.12	WSW	SW, 9	W	SW, 10	SW-WSW.
President Jackson, Am. S.S.	Yokohama	Victoria	45 30 N	164 50 E	Dec. 16	Mdt., 19	Dec. 18	28.66	S	W, 7	W	W, 9	W-WSW.
Do	do	do	47 42 N	174 28 E	Dec. 21	6a., 21	Dec. 21	29.01	E	E, 9	E	E, 10	NE-E.
Hanover, Am.S.S.	Los Angeles	Honolulu	24 15 N	149 11 W	Dec. 22	4a., 22	Dec. 22	29.69	SSE	SSE, 8	SW	SSW, 9	SSE-S.
Mojave, Am.S.S.	Manila	Los Angeles	43 00 N	155 30 W	do	Mdt., 22	Dec. 23	28.92	E	SSE, 9	S	ENE, 10	E-SSE-S.
Iwatesan Maru, Jap.S.S.	Yokohama	do	46 44 N	159 00 W	do	Noon, 23	do	[1]29.02	E	ENE	E	ENE, 11	E-ENE.
Michigan, Am.S.S.	Dairen	San Francisco.	41 12 N	156 30 W	Dec. 21	Mdt., 21	do	28.41	E	E, 8	SSW	SW, 10	ESE-E.
Hikawa Maru, Jap.M.S.	Yokohama	Seattle	50 03 N	155 13 W	Dec. 23	4a, 25	Dec. 25	28.77	E	E, 8	ESE	NE, 10	E-ESE.
Michigan, Am.S.S.	Dairen	San Francisco.	40 35 N	151 40 W	Dec. 24	11a., 24	do	28.47	WSW	NE, 4	SE	SW, 9	ESE-N-WNW.
Niagara, Br.S.S.	Honolulu	Victoria	29 10 N	151 01 W	do	4a., 24	Dec. 24	29.51	WSW	SW, 7	WSW	WSW, 8	
Mojave, Am.S.S.	Manila	Los Angeles	43 15 N	149 20 W	do	5p., 24	do	28.78	SSE	S, 9	SSW	SSW, 10	SSE-SSW.
Koyo Maru, Jap.S.S.	Yokohama	do	36 20 N	177 19 W	Dec. 23	Mdt., 24	do	29.24	WNW	WSW, 5	WNW	WNW, 8	WNW-WSW-W.
President Jackson, Am. S.S.	do	Victoria	49 49 N	155 44 W	Dec. 22	8a., 25	Dec. 25	28.68	E	E, 5	E	NE, 12	E-SE.
Tacoma, Am.S.S.	Darien	Vancouver	49 54 N	170 12 W	Dec. 28	10a., 28	Dec. 28	28.54	WSW	S, 7	SW	SW, 8	E-S-WSW.
Zuiyo Maru, Jap.S.S.	Yokohama	Los Angeles	39 27 N	155 39 W	Dec. 29	8p., 29	Dec. 30	29.60	WSW	WSW, 8	NNW	WNW, 10	SW-WSW-W.
President Pierce, Am.S.S.	do	Honolulu	32 58 N	167 54 E	do	Noon, 30	Dec. 31	28.92	S	SW, 10	W	SW, 10	SW-W.
Koyo Maru, Jap.S.S.	do	Los Angeles	36 27 N	143 09 W	Dec. 30	6p., 30	do	29.46	WNW	WNW, 8	WNW	WNW, 8	Steady.
New Orleans, Am.M.S.	Shanghai	do	42 35 N	152 40 W	Dec. 31	2a., 30	do	29.27	NW	W, 4	NW	NW, 8	SSW-W-WNW.

[1] Uncorrected.

NORTH PACIFIC OCEAN, DECEMBER 1933

By WILLIS E. HURD

Atmospheric pressure.—The pressure situation over the North Pacific Ocean in December 1933 was unusually abnormal, and constituted a reversal of usual conditions. During the first 24 days of the month high barometer prevailed over the Aleutian area, except for a few days in the Gulf of Alaska, and abnormally low pressure persisted during the greater part of December after the 8th in lower central waters of the ocean. At St. Paul the average barometer was 0.59 inch above the normal, and at Midway Island, it was 0.20 inch below. While heavy plus departures occurred down the American coast from Point Barrow to Juneau, Tatoosh Island stood out sharply with a minus departure of 0.18 inch.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, December 1933, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	30.30	+0.28	30.72	31	29.76	6
Dutch Harbor	30.10	+.54	30.72	12	29.02	26
St. Paul	30.17	+.59	30.74	12	29.10	29
Kodiak	29.94	+.39	30.50	10	29.02	5
Juneau	29.96	+.17	30.52	23	29.02	5
Tatoosh Island	29.78	−.18	30.27	23	29.21	11
San Francisco	30.11	−.01	30.47	17	29.61	31
Mazatlan	29.98	+.05	30.04	14, 20	29.86	7
Honolulu	30.00	−.01	30.19	29	29.68	22
Midway Island	29.81	−.20	30.10	4, 5	29.44	22
Guam	29.82	−.05	29.96	29	29.66	9
Manila	29.84	−.08	29.90	5, 31	29.78	14, 19, 27
Naha	30.06	−.02	30.20	4	29.76	29
Chichishima	29.93	−.07	30.16	4, 6	29.78	9
Nemuro	29.76		30.28	8	29.20	20

[1] For 22 days.

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

The average centers of high pressure this month lay between California and the Hawaiian Islands, over Bering Sea, and over southeastern Asiatic waters. The average centers of low pressure lay over midocean and the waters about northern Japan and the Kuril Islands.

The lowest recorded pressure reading for the month was 28.41, reported by the American steamer *Michigan*, on the 23d, in latitude 41°12′ N., longitude 156°30′ W. The highest reading was 30.74, reported on the 12th at St. Paul.

Cyclones and gales.—The scene of major storm activity on the North Pacific Ocean this month lay north of the thirtieth parallel, between longitude 165° W. and the American coast, which included a great region lying between the remarkable high pressure region over western Alaskan waters and the anticyclone situated southwest of California.

The coastal waters of Washington and Oregon were abnormally stormy, with cyclonic conditions prevalent during the greater part of the first 3 weeks of December. On the 1st and 2d fresh southerly gales swept this coast. On the 5th the American steamer *Tejon*, going south from Portland in the early morning, encountered southerly hurricane winds after passing outside the bar, and continued in violent winds until night. On the 11th and 12th fresh to whole southerly gales (forces 8 to 10) occurred here, and on the 17th to 20th high winds not only swept coastal waters, but, carried inland with heavy rains, caused thousands of dollars worth of damage over the western parts of the adjoining States.

Farther from the coast, to 165° W., gales were experienced on about half the days of the month between latitudes 35° and 50° N. They were particularly widespread on the 10th to 12th, with wind forces of 8 to 10 reported from most of the area and forces of 11 noted by two ships on the 10th and 11th, as indicated by the table of gales. On the 23d to 24th gales of force 11 to those of

hurricane velocity were reported from the region 45°–50° N., 155°–165° W.

The 10th to 11th were also stormy over much of the western part of the ocean along the northern and middle steamer routes between longitudes 150° and 170° E., with wind forces of 8 to 10 over much of the area. These dates, with the 16th to 18th, constitute the principal periods of storm activity in east longitudes.

Along the Lower California-Hawaiian routes very little stormy weather was experienced, although the usual trade winds were reduced in prevalence, owing to the southward extension of LOWS and the consequent intrusion of winds with westerly component during several days of the month. The principal gale noted in near-Hawaiian waters was that of the 22d, south-southwest, force 9, near 24° N., 148° W. On the 4th to 7th an east gale, varying in force from 8 to 9, was encountered as far south as about 11° N., 146° W.

Tehuantepecers.—Northers occurred in the Gulf of Tehuantepec as follows: Of force 9 on the 9th, and of force 7 on the 19th.

Fog.—The number of days on which fog was reported along the California coast was 6, which is less than half the number of days of occurrence in November. Along the west coast of Lower California 8 days with fog were reported, which is twice the number noted in November. Fog was mostly widely scattered elsewhere over the ocean, and occurred in the extreme on only 4 days in any given 5° square. In east longitudes it was reported on only 3 days altogether.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December 1933

[For description of table and charts, see REVIEW, January, p. 37]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	56.6	+8.9	3 stations	85	[1] 1	Riverton	15	28	3.22	−1.73	Citronelle	6.36	Geneva	1.36
Arizona	47.2	+2.8	Granite Reef Dam	88	25	Fort Valley	−5	17	.25	−.94	Williams	1.20	17 stations	.00
Arkansas	49.3	+6.5	Camden	83	5	Osceola	11	27	5.41	+1.11	Clarendon	12.01	Gravette	1.80
California	45.4	−.1	San Jacinto	90	8	Portola	−11	16	5.95	+2.23	Upper Mattole	25.40	2 stations	.00
Colorado	33.3	+8.0	2 stations	75	[1] 10	Sunbeam (near)	−24	17	1.17	+.25	Columbine	3.23	Delta	.03
Florida	64.3	+4.3	Fellsmere	89	26	Cottage Hill	26	8	.60	−2.20	Vernon	2.39	3 stations	.00
Georgia	55.3	+7.2	Fargo	85	[1] 17	Blairsville	11	[1] 10	1.79	−2.51	Dahlonega	5.11	Dover	.42
Idaho	34.2	+8.4	Glenns Ferry	75	11	Obsidian	−14	17	4.39	+2.41	Roland	28.23	Mud Lake	.14
Illinois	35.0	+4.5	Sparta	75	15	Freeport	−26	27	1.46	−.81	Golconda	3.45	Morrisonville	.43
Indiana	36.2	+3.9	Rome	77	15	Wheatfield	−13	27	2.26	−.64	Evans Landing	5.46	Goshen	.43
Iowa	27.1	+3.1	Clarinda	69	22	Fayette	−30	27	1.05	−.15	Keokuk No. 2	2.03	Tracy	.22
Kansas	39.6	+6.8	Medicine Lodge	78	10	Burr Oak	0	26	1.27	+.40	2 stations	2.78	Kismet	T
Kentucky	44.2	+6.3	Quicksand	75	17	Shelbyville	−5	27	4.99	+.97	Glasgow	7.97	Uniontown	2.19
Louisiana	61.6	+9.2	Dodson	87	2	2 stations	24	[1] 7	4.98	−.44	Robeline	10.46	Bogalusa	.46
Maryland-Delaware	36.5	+1.1	Hancock, Md	73	24	Oakland, Md	−10	28	3.00	−.15	Oakland, Md	4.80	Chewsville, Md	1.58
Michigan	23.8	−1.4	Midland	64	1	Vanderbilt	−37	29	1.87	−.21	Alpena (near)	4.24	Cassopolis	.41
Minnesota	10.8	−4.8	3 stations	53	[1] 4	Big Falls	−51	28	1.08	+.30	Park Rapids	3.16	New London	.24
Mississippi	56.9	+8.5	Columbia	85	16	3 stations	15	27	4.29	−1.07	Hernando	10.18	Poplarville	1.43
Missouri	39.1	+5.0	Warsaw	78	16	Downing	−7	27	1.82	−.25	New Madrid	4.65	Lucerne	.76
Montana	24.1	+1.3	Wyola	68	22	Frazer	−34	26	2.05	+1.16	Heron	15.92	Ennis	.07
Nebraska	32.6	+6.7	2 stations	76	[1] 22	3 stations	−17	26	1.17	+.47	Kearney	2.53	Culbertson	.10
Nevada	38.0	+7.4	do	75	[1] 12	Elko	−9	17	1.06	+.08	Lewers Ranch	5.83	Beatty	.02
New England	20.8	−5.8	Storrs, Conn	62	1	Bloomfield, Vt	−50	30	3.50	+.18	Lincoln, Maine	7.96	Bethlehem, N.H	1.32
New Jersey	31.8	−1.9	Tuckerton	72	1	Runyon	−18	28	3.19	−.46	Freehold	5.77	Layton	2.12
New Mexico	39.7	+5.9	Hagerman	90	12	Gavilan (near)	−16	17	.26	−.44	Bateman Ranch	2.14	60 stations	.00
New York	24.5	−2.3	Angelica	65	4	Philadelphia	−47	29	2.87	−.06	South Wales	5.13	Letchworth Park	1.46
North Carolina	48.3	+5.6	Belhaven	80	17	2 stations	7	[1] 27	1.73	−2.13	Rock House	5.66	Kenansville	.11
North Dakota	8.6	−4.0	New England	62	2	Langdon	−38	[1] 28	.88	+.36	Howard	2.35	Wishek	.00
Ohio	34.4	+2.7	Philo (1)	74	5	2 stations	−12	27	2.75	−.04	Portsmouth	6.84	Defiance	1.15
Oklahoma	46.5	+6.8	Hollis	84	10	do	9	27	1.59	−.12	Wyandotte	4.08	Goodwell	.03
Oregon	40.5	+7.2	2 stations	74	[1] 10	Sand Creek	−12	16	6.41	+2.62	Crossett	38.00	Lake	.07
Pennsylvania	31.7	+.6	Marcus Hook	74	1	Montrose	−22	29	2.88	−.28	Clymer	6.01	Montrose	1.30
South Carolina	52.1	+5.3	2 stations	82	[1] 18	2 stations	17	[1] 27	1.39	−2.24	Caesars Head	6.36	2 stations	.00
South Dakota	21.8	+1.1	do	70	22	La Delle	−32	26	.56	−.02	Forestburg	1.28	Ottumwa	T
Tennessee	48.5	+7.7	Milan	78	4	Cedar Hill	8	27	5.41	+.75	Moscow	12.89	Embreeville	1.96
Texas	56.7	+7.2	Laredo	95	5	Romero	9	18	1.88	−.31	Jefferson	9.22	21 stations	.00
Utah	33.7	+7.4	Piute Dam	70	13	Woodruff	−24	17	1.15	+.08	Silver Lake	6.09	Emery	T
Virginia	42.5	+4.4	Hopewell	81	23	Mount Weather	0	30	2.54	−.58	Pennington Gap	4.72	Norfolk	.66
Washington	38.1	+3.9	Wahluke	74	21	Stockdills Ranch	−9	27	14.49	+9.04	Cougar (near)	57.04	Mottinger	1.07
West Virginia	38.7	+4.0	Charleston	78	17	4 stations	−5	[1] 27	4.10	+.74	Sutton	6.15	Upper Tract	.87
Wisconsin	18.6	−1.8	2 stations	57	[1] 2	Rest Lake	−40	28	1.23	−.09	Flambeau Reservoir	2.62	Eau Claire	.41
Wyoming	30.4	+8.8	Barnum	73	23	Sage	−25	17	.61	−.14	Bechler River	6.00	3 stations	.0
Alaska (November)	16.7	+1.4	Ketchikan	56	1	Fort Yukon	−43	[1] 27	3.80	+.86	View Cove	30.89	Barrow	.11
Hawaii	70.8	+1.0	Pahala	90	.....	Kanaloholuhulu	39	1	6.19	−3.77	Eke	28.00	Puu Alaula	.00
Puerto Rico	74.1	−.3	2 stations	91	[1] 3	Guineo Reservoir	48	[1] 5	4.48	−.02	Rio Blanco	14.03	Mona Island	.22

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, December 1933*

[Compiled by ANNIE E. SMALL]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							24.2	−5.2										75	3.76	+0.3										7.3		
Eastport	76	67	85	29.94	30.03	+0.05	17.6	−8.7	44	6	26	−23	30	10	34	16	14	86	2.73	−1.0	17	10,122	nw.	46	e.	21	5	8	18	7.3	28.2	13.4
Greenville, Maine	1,070	6	.....	28.81	30.04	.....	10.0	.....	35	3	19	−32	29	1	35	.....	.....	.....	3.14	.....	13	6,223	nw.	29	.....	10	6	8	17	.....	42.4	.....
Portland, Maine	103	82	117	29.97	30.08	+.05	21.2	−6.4	43	18	28	−18	29	14	26	18	12	72	7.52	+3.6	20	6,878	n.	36	nw.	1	8	10	13	6.0	42.3	19.5
Concord	289	70	79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Burlington	403	11	48	29.63	30.11	+.06	16.2	−8.2	43	16	25	−29	30	7	44	.....	.....	.....	2.42	+.5	22	8,822	s.	38	nw.	1	1	8	22	8.3	17.0	5.8
Northfield	876	12	60	.....	30.11	+.06	14.6	−5.8	48	25	25	−38	30	4	43	.....	.....	88	2.43	−.1	19	5,734	n.	24	n.	18	1	5	25	8.6	20.7	11.0
Boston	125	106	165	29.93	30.07	+.02	26.8	−5.7	50	6	35	−17	29	19	28	24	16	65	2.93	−.5	13	11,712	w.	47	e.	26	4	10	17	7.1	15.6	7.5
Nantucket	12	14	90	30.04	30.05	.00	33.6	−2.2	51	6	40	−3	29	27	27	31	27	79	5.05	+1.3	17	12,081	w.	45	ne.	4	5	5	21	7.5	9.7	.0
Block Island	26	11	46	30.04	30.07	+.01	32.6	−3.4	53	6	39	−4	30	26	27	30	26	77	3.30	−.5	14	14,246	nw.	60	nw.	27	7	7	17	7.1	13.3	1.4
Providence	160	215	251	29.90	30.09	+.03	28.1	−3.5	52	6	36	−11	30	20	25	25	17	66	2.96	−.4	15	9,491	nw.	49	nw.	27	9	6	16	6.6	12.7	5.0
Hartford	159	70	104	.....	30.11	+.04	26.6	−3.2	49	6	34	−12	30	19	29	.....	.....	.....	3.72	−.2	15	6,283	s.	.....	.....	.....	6	6	19	.....	15.8	6.7
New Haven	106	74	153	29.99	30.11	+.04	29.2	−3.3	50	16	36	−8	29	22	27	26	20	70	4.51	+.5	14	7,140	n.	28	n.	26	7	8	16	6.8	16.4	5.4
Middle Atlantic States							36.6	+1.0										73	2.40	−0.9										6.8		
Albany	97	107	115	30.02	30.13	+.05	24.7	−3.8	47	18	33	−21	30	17	37	22	16	75	3.39	+.8	15	5,772	s.	21	nw.	1	6	5	20	7.2	17.2	6.5
Binghamton	871	60	68	29.14	30.11	+.02	27.0	−1.2	59	24	35	−17	29	19	35	.....	.....	.....	2.16	−.2	15	5,020	nw.	24	nw.	1	3	5	23	8.2	10.4	2.0
New York	314	414	454	29.76	30.11	+.02	32.9	−2.1	54	3	41	−6	30	25	30	29	23	69	3.33	−.3	11	10,542	nw.	56	nw.	11	7	6	18	6.9	13.2	6.6
Bellefonte	1,050	5	42	28.96	30.11	.....	28.1	.....	64	24	37	−6	29	19	35	26	23	85	2.35	.....	11	.....	w.	.....	.....	.....	4	8	19	7.4	~~7.9~~ 1.0	
Harrisburg	374	94	104	29.73	30.14	+.02	32.8	+.1	57	22	40	2	29	26	24	28	22	69	1.56	−1.5	9	5,583	w.	30	nw.	11	6	6	19	7.1	7.2	3.0
Philadelphia	114	123	367	30.02	30.15	+.04	36.2	−.1	61	22	43	3	30	29	28	31	24	64	2.52	−.9	11	9,135	sw.	41	nw.	11	8	7	16	6.5	5.1	1.6
Reading	323	283	304	29.77	30.14	.....	33.3	+1.1	59	24	41	0	30	26	30	29	23	68	1.91	−1.6	10	7,911	nw.	46	nw.	11	6	10	15	6.6	8.5	4.2
Scranton	805	72	104	29.23	30.12	+.02	28.8	−1.9	62	24	36	−10	29	22	27	26	23	78	2.15	−.9	13	5,467	nw.	28	nw.	1	3	10	18	7.5	13.7	3.0
Atlantic City	52	37	172	30.08	30.14	+.04	37.2	+.8	58	25	45	3	30	30	27	34	28	74	4.25	+.3	12	11,513	w.	42	w.	11	7	10	14	6.7	3.9	.0
Sandy Hook	22	10	57	30.09	30.12	.....	33.0	.....	54	25	39	−1	29	27	24	30	26	78	2.44	−1.6	13	11,029	w.	44	nw.	27	7	5	19	6.9	7.2	4.0
Trenton	190	159	183	29.92	30.14	.....	32.2	−2.2	57	22	40	−2	30	25	28	29	24	75	2.62	−.7	11	6,800	nw.	34	nw.	11	7	9	15	6.4	7.8	3.7
Baltimore	123	100	215	30.01	30.15	+.02	38.2	+1.0	63	24	46	6	30	30	28	33	27	68	2.47	−.9	13	7,155	sw.	37	nw.	11	8	7	16	6.4	7.2	2.0
Washington	112	62	85	30.03	30.15	+.02	38.5	+1.9	69	24	47	8	30	30	32	34	27	66	2.43	−.9	13	5,139	nw.	32	nw.	11	9	8	14	6.4	3.0	.0
Cape Henry	18	8	54	30.13	30.15	.....	47.3	+3.6	75	17	55	20	29	40	30	42	38	76	1.18	−2.3	7	9,370	sw.	44	nw.	9	6	13	12	6.1	T	.0
Lynchburg	681	153	188	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Norfolk	91	170	205	30.07	30.17	+.04	47.0	+3.9	72	17	55	18	30	39	27	42	37	74	.66	−2.7	7	9,356	sw.	38	w.	11	4	13	14	6.7	T	.0
Richmond	144	11	52	30.01	30.17	+.03	43.2	+3.4	74	17	53	12	30	34	30	37	32	72	3.14	−.2	9	6,185	sw.	24	nw.	11	7	12	12	6.1	.1	.0
Wytheville	2,304	49	55	27.71	30.15	.00	41.8	+6.5	66	17	51	12	27	32	36	36	32	74	2.18	−.7	9	5,722	w.	27	nw.	26	9	10	12	6.3	T	.0
South Atlantic States							54.1	+6.2										76	0.79	−2.5										5.2		
Asheville	2,253	89	104	27.78	30.18	+.02	46.8	+9.0	71	17	58	17	27	36	38	41	36	74	1.04	−2.2	7	6,703	nw.	28	nw.	26	12	7	12	5.6	T	.0
Charlotte	779	244	267	29.32	30.18	+.02	48.0	+5.0	70	1	56	20	30	40	20	43	37	70	1.79	−2.1	11	8,406	sw.	30	nw.	27	7	11	13	6.2	.0	.0
Greensboro	886	6	56	29.20	30.18	.....	44.2	.....	68	17	54	14	30	34	34	39	35	80	2.35	.....	11	6,024	sw.	26	n.	27	8	8	15	6.5	.0	.0
Hatteras	11	5	50	30.15	30.16	+.03	53.3	+3.2	72	17	60	31	29	47	20	49	46	80	.37	−3.8	5	9,828	sw.	35	nw.	9	10	13	8	5.0	T	.0
Raleigh	376	103	146	29.76	30.18	+.03	48.4	+5.4	71	17	58	15	30	39	27	42	36	70	.92	−2.7	8	6,640	sw.	26	ne.	6	13	5	13	5.7	.0	.0
Wilmington	72	73	106	30.11	30.18	+.03	54.2	+5.1	77	18	64	20	30	44	29	47	43	76	.19	−2.6	3	6,687	sw.	26	nw.	9	10	12	9	4.8	.0	.0
Charleston	48	11	92	30.12	30.17	+.02	58.0	+6.3	78	18	66	35	10	50	25	52	49	83	.40	−2.3	6	7,096	sw.	27	e.	29	15	7	9	4.5	.0	.0
Columbia, S.C	351	41	57	29.79	30.18	+.02	54.4	+7.2	78	18	64	26	30	44	32	47	42	72	.80	−2.2	12	5,253	sw.	25	sw.	3	12	9	10	5.1	.0	.0
Augusta	182	62	77	29.97	30.16	.00	55.4	+7.3	79	17	66	29	30	44	37	48	43	71	.83	−2.4	8	4,005	nw.	21	sw.	3	12	10	9	5.1	.0	.0
Savannah	65	73	152	30.10	30.17	+.02	59.6	+7.2	81	18	70	36	10	50	29	52	49	82	.86	−2.1	4	7,454	sw.	32	e.	29	17	6	8	4.3	.0	.0
Jacksonville	43	209	245	30.13	30.18	+.04	63.0	+6.7	80	18	72	39	10	54	28	56	52	79	.72	−2.3	5	7,729	sw.	27	w.	6	15	9	7	4.3	.0	.0
Florida Peninsula							69.9	+3.4										79	0.37	−1.4										2.8		
Key West	22	10	64	30.11	30.13	+.05	72.4	+2.1	82	4	77	61	10	68	14	67	65	83	.37	−1.3	3	6,937	ne.	22	n.	9	24	7	0	2.2	.0	.0
Miami	25	124	168	30.13	30.16	+.05	70.8	+2.8	81	4	76	50	10	65	21	64	61	76	.61	−1.1	4	7,024	e.	25	ne.	30	16	10	5	3.8	.0	.0
Tampa	35	88	197	30.13	30.17	+.05	66.4	+5.3	84	18	76	43	10	57	26	59	56	79	.13	−1.9	3	7,564	s.	28	e.	30	22	7	2	2.3	.0	.0
Titusville	44	5	25	30.12	30.17	.....	64.0	.....	81	6	76	40	10	52	35	.....	.....	.....	.50	.....	5	.....	w.	.....	.....	.....	19	9	3	.....	.0	.0
East Gulf States							58.4	+8.9										78	2.59	−2.3										5.1		
Atlanta	1,173	190	198	28.91	30.16	.00	51.9	+7.2	75	17	60	22	27	44	33	48	44	81	2.46	−2.2	12	7,646	w.	30	nw.	26	12	6	13	5.5	.0	.0
Macon	370	76	84	29.77	30.17	+.01	55.5	+8.0	78	17	66	29	10	44	36	48	44	74	2.10	−1.9	8	4,696	s.	21	nw.	26	10	10	11	5.5	.0	.0
Thomasville	273	49	103	29.89	30.19	+.04	60.8	+8.3	81	18	72	36	10	50	33	53	50	80	1.42	−2.9	5	.....	sw.	.....	.....	.....	12	9	10	.....	.0	.0
Apalachicola	35	11	19	30.13	30.17	.....	62.4	.....	76	6	70	41	27	54	26	58	.....	.....	.49	−4.6	4	.....	se.	.....	.....	.....	21	6	4	.....	.0	.0
Pensacola	56	149	185	30.10	30.16	+.01	62.2	+8.2	76	26	69	38	27	56	30	58	56	84	1.22	−3.4	6	9,648	s.	46	s.	3	16	10	5	3.9	.0	.0
Anniston	741	9	57	.....	.....	.....	55.1	+10.9	76	16	65	23	27	45	34	.....	.....	.....	2.44	−2.6	11	.....	nw.	.....	.....	.....	12	8	11	.....	.0	.0
Birmingham	700	11	48	29.37	30.15	−.01	56.0	+9.6	76	5	65	21	27	47	32	50	46	76	3.09	−2.0	9	6,299	s.	24	se.	19	10	10	11	5.5	.0	.0
Mobile	57	125	161	30.08	30.14	−.01	61.4	+9.2	79	3	70	36	27	53	29	56	53	82	3.86	−1.2	6	7,283	s.	26	nw.	6	8	15	8	4.8	.0	.0
Montgomery	218	92	105	29.92	30.17	+.01	58.5	+9.1	78	16	68	30	27	49	31	52	48	75	3.03	−1.8	9	5,315	s.	20	n.	6	12	5	14	5.5	.0	.0
Meridian	375	67	92	29.73	30.14	−.02	57.4	+9.7	80	16	68	25	27	46	36	50	48	79	4.76	−.5	11	5,056	sw.	25	nw.	6	10	14	7	4.8	.0	.0
Vicksburg	247	65	73	29.85	30.12	−.03	58.8	+8.8	79	17	68	27	27	50	29	52	48	73	4.97	−.4	9	6,137	s.	24	s.	15	10	8	13	5.6	.0	.0
New Orleans	53	76	84	30.09	30.14	+.01	64.7	+9.1	82	12	73	40	27	57	29	58	54	78	1.23	−3.6	6	5,132	sw.	18	nw.	6	12	10	9	4.6	.0	.0
West Gulf States							58.4	+8.0										73	2.49	−0.5										4.7		
Shreveport	249	92	227	29.81	30.09	−.04	58.2	+9.1	79	5	68	28	27	49	32	52	48	76	4.64	+.4	9	8,535	s.	33	sw.	14	15	6	10	5.0	.0	.0
Bentonville	1,303	11	44	28.66	30.05	−.08	45.3	+7.8	73	1	56	16	27	35	32	.....	.....	.....	2.20	.....	8	5,491	sw.	22	sw.	14	12	7	12	.....	2.5	.0
Fort Smith	457	79	94	29.58	30.07	−.06	48.4	+6.3	78	4	58	21	27	39	33	42	36	69	1.92	−.8	7	6,724	e.	24	s.	14	12	10	9	5.2	.0	.0
Little Rock	357	94	102	29.72	30.10	−.04	48.8	+4.6	75	5	58	18	27	40	31	44	39	73	3.52	−.6	8	6,686	sw.	25	sw.	10	7	7	17	6.8	.0	.0
Austin	605	136	148	29.42	30.06	.....	59.6	+8.6	83	20	72	31	7	48	45	51	43	63	1.24	−1.4	6	6,679	s.	36	nw.	18	13	9	9	4.5	.0	.0
Brownsville	57	88	96	29.98	30.04	.....	68.8	+7.6	85	3	76	44	7	61	28	62	59	81	.05	−1.5	2	8,063	s.	30	s.	11	20	7	4	3.3	.0	.0
Corpus Christi	20	11	78	30.06	30.08	−.04	67.3	+9.3	87	5	76	43	19	59	35	61	58	80	.31	−1.1	7	8,333	s.	30	s.	14	13	10	8	4.7	.0	.0
Dallas	512	220	227	29.50	30.05	.....	53.7	.....	80	13	64	25	27	43	36	47	40	66	3.61	+1.2	7	8,834	s.	34	nw.	5	15	5	11	4.1	.0	.0
Fort Worth	670	106	114	29.34	30.06	−.06	54.0	+6.5	83	13	66	25	27	42	41	.....	.....	.....	2.13	+.3	5	6,222	sw.	25	sw.	14	17	6	8	3.9	.0	.0
Galveston	54	106	114	30.03	30.09	−.03	65.6	+7.9	78	12	71	45	27	60	19	61	59	85	5.54	+1.8	9	8,112	s.	32	nw.	6	17	5	9	3.9	.0	.0
Houston	138	292	314	29.94	30.09	.....	64.4	+10.0	84	3	73	40	28	56	27	.....	.....	.....	3.27	−1.0	10	8,942	s.	30	nw.	5	13	5	13	5.3	.0	.0
Palestine	510	64	72	29.54	30.08	−.04	57.8	+7.9	81	13	68	34	27	48	37	51	46	72	3.80	+.1	9	6,527	s.	28	sw	24	13	7	11	4.9	.0	.0
Port Arthur	34	58	66	30.05	30.09	.....	63.8	.....	81	3	71	39	7	57	25	.....	.....	.....	1.90	−3.3	10	6,831	s.	24	nw.	5	9	16	6	5.2	.0	.0
San Antonio	693	242	301	29.32	30.04	−.07	62.5	+8.8	83	3	74	35	28	52	35	53	45	63	.39	−1.2	4	8,507	s.	35	w.	18	13	10	8	4.6	.0	.0

TABLE 1.—*Climatological data for Weather Bureau Stations, December 1933*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*Pct.*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							41.8	**+5.0**										**75**	**3.93**	**+0.3**										**7.3**		
Chattanooga	762	190	215	29.34	30.17	+0.0	51.1	+7.8	72	3	60	21	27	43	34	45	40	72	3.57	−1.6	12	5,994	se.	27	sw.	3	10	7	14	6.2	0.0	0.0
Knoxville	995	79	97	29.08	30.16	.00	48.8	+8.5	72	17	57	18	27	40	30	43	39	74	3.33	−1.2	12	5,164	ne.	24	sw.	15	10	7	14	5.7	T	.0
Memphis	399	78	86	29.68	30.11	−.04	49.4	+5.8	73	4	57	15	27	42	31	45	41	77	10.75	+6.2	8	6,648	sw.	23	n.	6	7	9	15	6.6	.0	.0
Nashville	546	168	191	29.56	30.16	+.01	48.2	+7.2	70	15	57	12	27	40	25	44	39	73	6.40	+2.2	15	7,623	s.	31	nw.	24	2	15	14	6.9	T	.0
Lexington	989	193	230																												
Louisville	525	188	234	29.56	30.16	+.02	41.7	+4.1	68	15	50	0	27	34	26	38	32	71	3.69	.0	13	8,405	s.	34	sw.	3	4	7	20	7.5	4.3	.0
Evansville	431	76	116	29.65	30.13	.00	42.0	+4.9	70	15	50	1	27	34	32	38	33	73	2.69	−.8	9	7,634	s.	30	sw.	15	2	11	18	7.6	4.0	.0
Indianapolis	822	194	230	29.21	30.13	+.01	36.0	+3.8	69	15	44	−3	27	28	33	33	28	71	2.17	−.8	9	8,530	s.	29	nw.	26	1	5	25	8.4	1.8	.0
Terre Haute	575	96	129	29.48	30.12		37.9		69	15	46	0	27	30	33	34	30	76	1.42	−1.5	9	7,579	s.	30	s.	3	3	9	19	7.6	1.2	.0
Cincinnati	627	11	51	29.45	30.14	+.01	38.6	+5.2	67	5	46	−4	27	31	26	35	31	78	2.95	.0	13	6,430	sw.	24	nw.	24	3	5	23	8.0	4.0	.0
Columbus	822	216	230	29.24	30.14	+.02	35.6	+3.2	64	5	43	−2	27	28	31	33	29	78	2.45	−.3	10	8,655	s.	37	w.	10	3	9	19	7.5	7.8	.0
Elkins	1,947	59	67	28.06	30.18	+.06	38.2	+5.5	69	17	49	2	27	28	38	34	30	78	4.51	+1.0	14	5,073	w.	32	w.	20	3	6	22	7.8	6.5	.0
Parkersburg	637	77	82	29.51	30.18	+.04	38.8	+3.6	69	17	48	1	27	30	34	35	31	77	3.60	+.6	13	5,037	nw.	26	nw.	24	8	4	19	7.3	5.1	.0
Pittsburgh	842	353	410	29.21	30.14	+.03	35.3	+1.1	63	23	43	1	27	27	34	32	28	74	3.42	+.6	10	8,016	w.	38	nw.	11	5	4	22	7.9	7.0	.0
Lower Lake Region							**28.0**	**−1.2**										**80**	**2.24**	**−0.5**									**8.4**		
Buffalo	767	243	280	29.22	30.08	+.02	27.1	−2.7	53	3	34	−7	29	20	43	26	23	84	3.76	+.4	20	12,550	w.	49	sw.	17	4	6	21	8.0	19.3	1.0
Canton	448	10	61	29.58	30.09		13.3	−9.4	46	5	23	−34	29	4	52				3.49	+.8	18	6,972	w.	29	w.	18	6	4	21	7.3	17.6	8.3
Ithaca	836	74	100	29.16	30.10		27.4	−1.6	55	24	35	−13	29	20	36	25	21	78	2.04	−.3	19	8,557	se.	36	se.	25	1	4	26	9.0	11.7	T
Oswego	335	71	85	29.72	30.10	+.04	24.8	−4.2	52	5	33	−23	29	17	39	23	21	85	2.55	−1.0	19	9,130	se.	41	nw.	1	0	4	27	9.1	17.8	6.2
Rochester	523	86	102	29.51	30.11	+.05	27.5	−1.8	57	5	35	−7	29	20	39	25	21	76	2.57	−.2	23	5,720	w.	28	w.	17	3	3	25	8.9	17.2	2.0
Syracuse	596	65	79	29.45	30.12	+.05	26.2	−2.1	55	24	35	−24	29	18	42				2.24	−.8	18	6,381	w.	26	nw.	1	1	7	23	8.4	12.8	.5
Erie	714	130	166	29.31	30.10	+.03	31.7	−.2	61	15	39	0	29	25	33	29	25	77	2.67	−.2	19	10,630	s.	41	nw.	11	1	5	25	8.4	8.1	.0
Cleveland	762	267	337	29.26	30.10	+.01	33.6	+2.4	66	15	41	3	27	26	39	30	26	75	1.60	−.8	14	10,821	w.	46	w.	11	1	6	24	8.6	9.5	.0
Sandusky	629	5	67	29.42	30.12	+.03	32.1	+.9	67	15	40	−4	27	25	39				1.74	−.5	11	7,514	sw.	32	nw.	11	0	7	24	8.5	6.5	.0
Toledo	628	79	87	29.42	30.12	+.04	30.8	+.4	65	15	38	−2	27	24	37	28	25	79	1.75	−.6	10	7,200	w.	27	w.	15	3	5	23	8.3	8.1	.0
Fort Wayne	857	69	84	29.16	30.12		31.2	+3.9	64	15	38	−4	27	24	31	29	26	82	1.14	−1.4	10	7,083	sw.	27	sw.	15	1	7	23	8.1	6.1	.0
Detroit	730	218	258	29.30	30.12	+.05	29.8	+.5	61	15	36	−2	27	23	32	27	24	82	1.38	−1.0	11	7,841	sw.	32	sw.	15	1	6	24	8.4	6.6	.0
Upper Lake Region							**21.8**	**−2.5**										**83**	**1.94**	**−0.1**									**8.1**		
Alpena	609	13	89	29.40	30.10	+.08	22.0	−2.8	45	2	28	−14	29	16	23	20	17	84	2.85	+.8	20	8,637	nw.	37	se.	15	2	11	18	7.8	28.2	8.5
Escanaba	612	54	60	29.42	30.11	+.08	17.5	−4.9	41	4	24	−17	27	11	29	17	14	83	2.23	+.5	16	7,802	nw.	31	n.	31	7	4	20	7.4	20.3	9.0
Grand Rapids	707	70	244	29.32	30.12	+.07	28.0	−.5	55	15	34	1	27	22	27	26	23	80	1.74	−.8	19	8,203	sw.	32	sw.	15	0	5	26	9.0	14.0	T
Lansing	878	6	88	29.13	30.10		26.2	−1.0	57	15	33	−7	27	19	31	25	24	94	1.50	−.6	16	7,158	sw.	28	nw.	10	2	4	25	8.7	10.4	.0
Ludington	637	60	66	29.37	30.09		26.3	−2.1	48	3	30	3	27	22	19	25			2.11	−.4	21		se.				0	3	28		11.2	.1
Marquette	734	77	111	29.25	30.09	+.07	18.3	−4.3	46	2	25	−11	27	12	24	16	14	86	2.56	−.1	21	8,590	w.	43	sw.	18	1	7	23	8.4	20.2	11.0
Sault Ste. Marie	614	11	52	29.37	30.11	+.11	15.2	−5.3	41	2	23	−24	29	7	27	14	12	89	3.25	+.9	25	6,751	se.	35	nw	22	1	6	24	8.3	29.5	13.2
Chicago	673	7	131	29.36	30.11	+.03	31.3	+2.5	58	23	38	−9	27	25	27	29	25	76	1.39	−.6	9	8,072	nw.	26	se.	14	0	9	22	8.4	7.1	.0
Green Bay	617	109	141	29.41	30.10	+.06	20.4	−1.9	45	4	28	−17	25	13	29	19	15	78	1.19	−.5	16	8,135	w.	30	nw.	10	5	5	21	7.8	7.3	T
Milwaukee	681	97	221	29.34	30.11	+.05	26.4	+.3	55	3	33	−11	27	20	31	25	21	76	1.13	−.6	10	9,928	nw.	42	se.	14	1	8	22	8.4	8.3	T
Duluth	1,133	5	47	28.82	30.12	+.07	8.6	−7.3	38	4	18	−32	25	−1	41	9	7	88	1.34	+.2	12	9,834	nw.	49	nw.	20	5	8	18	6.9	21.0	10.2
North Dakota							**8.0**	**−4.4**										**85**	**1.32**	**+0.7**									**7.0**		
Moorhead, Minn	940	50	58	29.07	30.16	+.08	7.2	−4.3	44	1	18	−31	25	−3	45	6	4	91	1.70	+1.0	10	6,691	s.	25	n.	10	5	4	22	7.7	21.9	9.6
Bismarck	1,674	8	57	28.22	30.11	+.03	12.0	−2.7	56	6	22	−23	25	2	41	9	6	79	.43	−.1	7	6,056	e.	29	nw.	10	6	7	18	7.2	7.0	3.7
Devils Lake	1,478	11	44	28.46	30.14	+.08	3.8	−5.7	47	6	14	−30	28	−6	39	2	0	90	1.05	+.5	14	7,287	nw.	32	nw.	21	8	4	19	6.7	9.9	5.0
Grand Forks	833	12	67				3.4		45	6	14	−37	28	−7	38	1			1.47		12		nw.	32	nw.	20	9	5	17		14.4	11.8
Williston	1,878	41	48	28.01	30.10	+.04	8.8	−5.0	49	6	18	−26	25	−1	41	7	4	80	2.11	+1.5	13	5,444	sw.	25	nw.	20	7	9	15	6.2	21.2	18.6
Upper Mississippi Valley							**29.7**	**+2.9**										**78**	**1.30**	**−0.4**									**7.5**		
Minneapolis	918	102	208	29.08	30.11		17.0	−2.6	49	4	26	−19	28	8	36	16	12	79	.71	−.3	9	7,987	nw.	31	nw.	20	4	6	21	7.7	5.1	1.0
La Crosse	714	11	48	29.31	30.12	+.04	21.8	−.5	52	4	30	−22	27	14	34	20	17	83	.59	−.7	11	4,314	s.	16	nw.	10	4	3	24	7.9	5.3	T
Madison	974	70	78	29.01	30.12	+.04	23.4	+.6	50	3	30	−17	27	17	25	22	20	87	.85	−.8	11	7,004	nw.	27	nw.	10	3	7	21	8.1	5.3	T
Charles City	1,015	10	51	29.00	30.13	+.03	21.8	+1.4	51	4	31	−25	27	12	39	20	16	80	1.10	−.2	9	5,616	se.	22	se.	14	6	4	21	7.0	6.4	T
Davenport	606	118	143	29.44	30.12	+.02	30.0	+2.9	60	4	38	−11	27	22	27	27	23	79	1.84	+.4	9	7,562	nw.	28	nw.	24	3	7	21	8.1	4.1	T
Des Moines	861	5	99	29.17	30.11	.00	28.8	+2.8	64	22	39	−6	26	19	38	26	21	75	.77	−.4	5	7,201	n.	27	se.	14	7	11	13	6.5	.8	.0
Dubuque	700	81	96	29.34	30.12	+.02	26.0	+1.3	57	4	34	−18	27	18	31	24	20	78	1.62	+.2	5	5,322	se.	21	nw.	20	4	2	25	8.3	6.2	T
Keokuk	614	64	78	29.43	30.13	+.01	34.2	+4.6	67	23	43	−4	27	25	32	30	24	70	1.74	+.3	7	6,238	sw.	24	w.	15	5	7	19	7.5	.4	.0
Cairo	358	87	93	29.73	30.12	+.03	44.5	+6.7	72	15	53	8	27	36	32	40	35	73	2.60	−.8	8	7,938	s.	26	n.	5	4	12	15	6.9	T	.0
Peoria	609	11	45	29.44	30.13	+.02	32.6	+4.5	65	23	40	−4	27	25	33	29	26	78	1.18	−.6	10	5,775	s.	21	w.	15	6	7	18	7.0	1.5	.0
Springfield, Ill	636	5	191	29.41	30.11	−.01	36.0	+4.3	66	23	44	0	27	28	32	33	29	81	.91	−1.3	6	8,953	s.	31	nw.	26	3	9	19	7.6	.5	.0
St. Louis	568	265	303	29.48	30.11	−.02	40.2	+5.5	72	23	49	4	27	31	32	35	29	68	1.70	−.5	5	9,174	s.	36	sw.	2	6	9	16	6.9	2.2	.0
Missouri Valley							**34.1**	**+5.3**										**70**	**1.45**	**+0.3**									**5.5**		
Columbia, Mo	784	6	84	29.25	30.11	−.01	38.0	+4.8	70	4	48	4	26	28	35				1.94	+.1	6	6,831	sw.	25	sw.	15	12	6	13	5.6	.2	.0
Kansas City	963	10	86	29.04	30.10	−.02	39.0	+6.5	67	14	48	6	26	30	37	33	26	62	1.80	+.5	3	7,495	sw.	31	nw.	24	8	12	11	6.1	T	.0
St. Joseph	967	11	49	29.03	30.09		36.4		65	22	46	3	26	26	34	30	24	67	1.41	+.4	4	6,604	se.	27	nw.	24	18	4	9	4.4	.1	.0
Springfield, Mo	1,324	98	104	28.65	30.08	−.05	43.1	+6.9	74	4	53	12	27	34	32	38	33	73	.84	−1.5	5	8,039	se.	24	sw.	31	13	8	10	5.1	T	.0
Iola	984	11	50	29.01	30.08	−.04	42.4	+8.5	71	14	54	7	26	31	37				2.57	+1.2	5		s.				12	8	11		T	.0
Topeka	987	92	107				38.4	+6.4	70	14	50	5	26	27	38				1.49	+.5	4	6,745	s.	27	nw.	24	19	5	7	3.9	T	.0
Lincoln	1,189	11	81	28.78	30.09	−.03	32.8	+5.2	70	22	43	−4	26	22	36	28	22	68	1.67	+.9	4	6,989	s.	30	nw.	23	8	13	10	5.6	.5	.0
Omaha	1,105	115	122	28.88	30.10	−.01	31.3	+4.9	63	22	41	−5	26	22	37	27	21	67	1.39	+.5	2	6,320	nw.	32	nw.	24	11	9	11	5.5	T	.0
Valentine	2,598	47	54	27.27	30.08	−.02	29.8	+5.2	70	22	42	−10	26	17	49	24	18	69	.53	−.1	3	6,561	w.	38	nw.	23	6	11	14	6.4	2.2	T
Sioux City	1,135	94	164	28.83	30.10	−.02	27.0	+3.9	61	22	37	−15	26	17	43	24	19	76	1.81	+.9	4	7,027	nw.	32	nw.	24	10	7	14	6.1	.6	T
Huron	1,306	59	74	28.65	30.12	+.02	19.0	+.3	60	21	29	−21	26	9	45	16	13	79	.53	.0	6	6,867	se.	25	n.	10	6	9	16	6.6	5.4	.6
Northern Slope							**29.2**	**+5.4**										**70**	**0.92**	**+0.1**									**7.1**		
Billings	3,140	5					26.8		63	22	39	−9	26	15	53				.82		8		nw.				3	8	20		0.5	
Havre	2,505	11	67	27.27	30.03	−.02	16.3	−4.1	56	2	27	−18	26	5	51	12	9	82	.92	+.3	11	7,710	e.	38	sw.	21	3	9	19	7.7	14.1	1.3
Helena	4,124	89	113	25.66	29.94	−.19	30.2	+6.0	60	21	38	−3	26	22	43	26	20	68	.60	−.2	11	6,046	sw.	48	sw.	21	2	5	24	8.2	5.2	T
Kalispell	2,973	48	56	26.79	29.90	−.17	31.3	+6.4	55	22	37	6	26	25	23	29	27	85	3.22	+1.8	21	5,983	nw.	29	sw.	21	0	7	24	8.5	14.5	.0
Miles City	2,371	48	55	27.43	30.08	−.02	20.5	−.5	54	6	30	−18	26	10	40	18	14	79	.79	+.2	10	4,392	s.	30	nw.	23	3	12	16	7.5	8.7	3.9
Rapid City	3,252	50	58	26.54	30.07	−.02	29.9	+3.0	67	29	42	−14	26	18	62	25	18	67	.23	−.2	4	5,386	w.	38	n.	23	1	12	18	7.5	2.7	T
Cheyenne	6,094	50	71	23.94	29.98	−.11	39.0	+10.5	63	29	50	7	26	28	40	30	20	49	.54	.0	3	11,180	w.	45	w.	10	6	17	8	5.6	4.6	.0
Lander	5,372	60	68	24.57	30.02	−.13	34.0	+13.6	65	10	48	6	26	20	46	27	19	59	T	−.7	0	4,816	sw.	41	sw.	12	11	15	5	4.8	.0	.0
Sheridan	3,790	10	47	26.00	30.01		28.2		67	22	41	−18	26	15	59	22	15	67	.43	−.2	5	3,986	nw.	31	nw.	23	3	8	20	7.5	7.0	1.8
Yellowstone Park	6,241	11	48	23.81	30.06	−.10	28.6	+7.0	43	28	35	9	5	22	28	26	20	69	1.38	−.1	22	8,808	sw.	30	sw.	19	1	7	23	8.6	23.4	3.6
North Platte	2,821	11	51	27.05	30.06	−.04	33.3	+6.6	69	22	45	2	26	22	40	27	21	70	1.06	+.5	4	5,437	w.	32	n.	23	11	10	10	5.4	.2	.0

TABLE 1.—*Climatological data for Weather Bureau stations, December 1933*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	*In.*	*In.*	*In.*		*Miles*							*0–10*	*In.*	*In.*
Middle Slope							**41.4**	**+8.0**										**59**	**1.14**	**+0.3**										**4.2**		
Denver	5,292	106	113	24.68	29.97	−0.11	43.8	+11.5	69	22	55	13	26	32	36	34	20	42	.82	+.1	2	6,157	s.	29	w.	6	11	15	5	4.6	8.4	.0
Pueblo	4,685	80	86	25.27	30.02	−.06	41.6	+10.1	71	22	55	12	6	28	47	32	21	52	1.09	+.6	2	5,892	w.	35	w.	14	13	15	3	3.9	10.4	.0
Concordia	1,392	50	58	28.60	30.11	.00	36.9	+6.2	71	23	48	4	26	26	35	30	24	67	.74	+.1	1	5,953	sw.	27	n.	24	14	10	7	4.5	.0	.0
Dodge City	2,509	10	86	27.43	30.09	−.01	40.4	+7.8	72	22	54	8	26	27	41	31	24	64	.75	+.2	1	8,103	w.	33	sw.	14	20	8	3	2.7	.0	.0
Wichita	1,358	85	93	28.60	30.07	−.04	40.6	+6.0	69	14	51	10	26	31	33	34	27	64	1.85	+.8	4	7,931	sw.	28	sw.	14	13	8	10	5.2	.0	.0
Oklahoma City	1,214	10	47	28.76	30.07	−.04	45.4	+6.1	74	14	56	16	26	35	33	38	32	67	1.61	+.1	4	7,186	s.	25	n.	26	15	5	11	4.4	.0	.0
Southern Slope							**51.2**	**+7.1**										**48**	**0.47**	**−0.4**										**2.8**		
Abilene	1,738	10	52	28.23	30.06	−.05	52.0	+6.0	83	4	65	19	27	39	42	40	29	51	1.64	+.3	5	6,766	s.	26	s.	1	16	8	7	3.9	.3	.0
Amarillo	3,676	10	49	26.28	30.05	−.04	47.4	+10.4	80	10	62	15	27	33	44	34	21	45	.02	−.8	1	6,740	w.	30	w.	14	24	5	2	2.1	.0	.0
Big Spring	2,537	5	62	27.42	30.08	.....	49.9	.....	82	10	66	18	27	34	50	36	25	49	.33	.....	2	.....	s.	.....	.....	.....	21	6	4	2.5	.0	.0
Del Rio	944	64	71	29.04	30.04	−.06	58.6	+6.4	84	12	72	33	19	45	42	47	37	55	.21	−.5	4	5,303	nw.	30	nw.	5	17	5	9	4.0	.0	.0
Roswell	3,566	75	85	26.42	30.07	.00	46.8	+5.6	77	7	64	15	18	30	51	36	21	40	T	−.7	0	5,042	s.	32	sw.	14	25	3	3	1.7	.0	.0
Southern Plateau							**46.0**	**+4.2**										**53**	**0.22**	**−0.5**										**2.0**		
El Paso	3,778	152	175	26.28	30.12	+.09	50.1	+5.2	75	25	64	24	18	36	36	37	21	34	.00	−.5	0	6,567	nw.	38	w.	14	29	2	0	.7	.0	.0
Albuquerque	4,972	51	66	25.14	30.16	.....	38.8	.....	65	27	55	16	18	23	42	29	21	59	.05	.....	1	5,142	n.	43	w.	14	20	10	1	2.5	.2	.0
Santa Fe	7,013	38	53	23.29	30.14	+.08	37.4	+6.3	59	27	48	14	17	26	28	28	20	56	.47	−.3	3	5,217	n.	21	nw.	14	20	9	2	2.8	5.4	.0
Flagstaff	6,907	10	59	23.41	30.13	+.07	34.9	+6.5	63	7	50	6	1	20	43	27	.....	74	.62	.....	5	5,431	n.	23	w.	14	14	12	5	.....	2.0	T
Phoenix	1,108	10	107	28.93	30.10	+.06	54.6	+2.6	80	9	69	29	18	40	39	44	34	52	T	−1.0	0	3,579	e.	19	n.	16	24	3	4	2.5	.0	.0
Yuma	141	9	54	29.96	30.10	+.05	57.1	+1.9	77	12	70	34	1	44	33	45	31	42	.09	−.4	2	4,204	n.	21	w.	13	25	5	1	1.7	.0	.0
Independence	3,957	6	27	26.07	30.17	+.05	41.6	+2.3	62	29	55	16	16	29	34	33	.....	.....	.50	−.3	6	.....	nw.	.....	.....	.....	16	4	11	.....	.1	.0
Middle Plateau							**37.1**	**+6.8**										**66**	**0.80**	**−0.2**										**5.4**		
Reno	4,532	74	81	25.50	30.10	−.05	39.6	+5.9	62	6	51	9	17	28	36	33	26	62	2.06	+1.1	8	4,250	sw.	28	se.	11	10	13	8	5.2	2.8	.0
Tonopah	6,090	12	20	.....	.....	.....	38.4	.....	58	10	45	14	17	31	22	32	25	61	.03	.....	3	.....	se.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Winnemucca	4,344	18	56	25.66	30.13	−.05	36.9	+6.9	63	11	50	7	17	24	39	30	24	66	.69	−.4	8	5,566	sw.	26	s.	13	9	8	14	6.0	1.7	.0
Modena	5,473	10	46	24.68	30.12	.00	36.5	+8.4	64	26	49	4	17	24	38	29	24	69	.38	−.4	5	6,889	sw.	35	sw.	12	12	7	12	5.3	.8	.0
Salt Lake City	4,360	86	210	25.69	30.12	−.03	39.7	+7.8	62	11	48	13	17	31	27	34	27	62	.51	−.9	6	4,874	s.	27	nw.	13	8	12	11	5.6	3.6	.0
Grand Junction	4,602	60	68	25.50	30.18	+.08	32.6	+5.1	59	13	43	8	18	22	28	28	23	74	.34	−.3	7	3,594	nw.	22	w.	14	12	9	10	4.8	1.6	.0
Northern Plateau							**39.7**	**+9.1**										**72**	**2.42**	**+0.7**										**8.4**		
Baker	3,471	48	53	26.40	30.03	−.13	37.4	+10.1	57	22	44	8	16	31	23	34	30	74	1.50	−.2	18	5,680	se.	26	sw.	6	1	7	23	8.2	6.5	.0
Boise	2,739	79	87	27.19	30.09	−.11	42.4	+10.3	63	11	49	20	16	35	23	37	30	64	1.10	−.5	13	4,961	se.	24	se.	17	2	3	26	8.5	.6	.0
Pocatello	4,477	60	68	25.50	30.10	−.09	38.0	+10.3	61	10	46	14	17	30	28	32	25	62	1.92	+.7	6	9,659	se.	30	s.	12	3	13	15	7.0	3.8	.0
Spokane	1,929	101	110	27.82	29.90	−.18	37.8	+7.3	59	21	43	20	16	33	20	36	33	83	4.35	+2.2	22	6,755	s.	30	s.	21	2	1	28	9.1	2.8	.0
Walla Walla	991	57	65	28.85	29.94	−.18	44.4	+8.9	70	21	51	22	26	38	25	40	34	70	3.48	+1.4	22	5,882	s.	32	s.	17	0	5	26	9.2	13.6	.3
Yakima	1,076	58	67	28.75	29.91	.....	38.4	+7.7	65	21	45	22	4	32	25	36	33	81	2.18	+.8	19	3,783	nw.	22	sw.	20	2	4	25	8.5	7.5	3.3
North Pacific Coast Region							**46.1**	**+3.6**										**85**	**12.93**	**+5.7**										**9.4**		
North Head	211	11	56	29.62	29.85	−.18	46.2	+2.1	53	28	49	34	15	43	10	46	45	93	21.85	+12.4	31	16,810	s.	70	s.	17	0	2	29	9.4	T	.0
Seattle	125	90	321	29.71	29.84	−.17	45.1	+3.4	57	21	49	34	16	41	19	43	40	84	15.33	+9.7	26	9,624	s.	42	sw.	19	0	3	28	9.6	T	.0
Tatoosh Island	86	10	54	29.68	29.78	−.18	44.2	+.3	53	20	47	34	15	41	16	43	41	89	16.26	+2.9	29	15,208	e.	63	s.	20	0	2	29	9.5	1.0	.0
Medford	1,329	29	58	28.60	30.03	.....	41.2	.....	59	12	49	22	1	34	24	39	36	83	1.99	−1.1	16	4,756	n.	34	se.	11	0	2	29	9.4	T	.0
Portland, Oreg	153	68	106	29.76	29.91	−.16	46.6	+5.4	60	9	50	34	15	43	13	44	42	84	17.45	+10.7	26	6,136	sw.	27	s.	5	0	0	31	9.5	.1	.0
Roseburg	510	45	76	29.43	29.99	−.12	48.4	+6.6	66	9	55	33	1	42	25	45	41	78	4.69	−.6	19	3,487	sw.	25	s.	18	0	1	30	9.5	T	.0
Middle Pacific Coast Region							**47.8**	**−0.1**										**84**	**6.19**	**+1.8**										**7.6**		
Eureka	62	73	89	29.99	30.06	−.06	50.2	+2.0	63	20	56	34	16	44	21	48	45	82	6.50	+.2	14	6,064	se.	27	se.	2	4	9	18	7.5	.0	.0
Red Bluff	330	5	58	29.76	30.13	−.01	45.0	−1.1	62	21	51	30	16	39	24	43	40	86	8.33	+3.9	17	4,216	nw.	30	se.	12	3	4	24	8.3	.0	.0
Sacramento	69	106	117	30.06	30.14	.00	45.6	−.6	63	12	51	33	16	40	24	44	41	85	5.74	+2.7	12	4,928	se.	24	s.	12	4	11	16	7.2	.0	.0
San Francisco	155	208	243	29.94	30.11	−.01	50.5	−.8	64	12	55	39	25	46	13	47	44	81	4.19	+.2	11	5,045	n.	29	sw.	11	4	8	19	7.3	.0	.0
South Pacific Coast Region							**53.0**	**0.0**										**74**	**3.72**	**+1.7**										**5.6**		
Fresno	327	97	105	29.80	30.16	+.03	46.4	+.2	69	11	54	31	20	38	28	43	39	80	1.59	+.1	8	3,440	e.	25	s.	13	5	8	18	7.6	.0	.0
Los Angeles	338	159	191	29.76	30.14	+.07	57.4	+.8	85	8	66	40	25	49	31	48	41	65	8.48	+5.8	7	4,430	ne.	22	se.	31	15	8	8	4.6	.0	.0
San Diego	87	62	70	30.02	30.12	+.05	55.1	−.9	72	20	62	42	17	48	23	50	46	76	1.10	−.8	6	4,097	nw.	24	s.	13	14	8	9	4.6	.0	.0
West Indies																																
San Juan, P.R.	82	9	54	29.92	30.01	.....	76.7	+.4	83	12	81	68	30	72	11	.....	.....	.....	4.77	−.7	22	9,868	e.	34	ne.	16	4	24	3	5.2	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cristobal	36	6	97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Alaska																																
Fairbanks	454	11	87	.....	[1] 30.42	.....	−27.0	.....	25	11	−20	−54	31	−34	38	−26	−29	84	.96	.....	8	1,664	n.	22	sw.	12	17	4	10	3.9	15.7	27.0
Juneau	80	11	50	[1] 29.86	[1] 29.96	.....	13.0	.....	33	11	17	−10	18	9	18	10	0	54	.88	.....	6	8,716	ne.	35	e.	16	18	3	10	3.7	12.3	.6
Hawaiian Islands																																
Honolulu	38	86	100	[1] 29.96	[1] 30.00	.....	73.8	+1.4	82	11	79	65	22	69	16	69	66	80	3.33	−.6	8	5,472	e.	36	sw.	23	15	5	11	5.5	.0	.0

[1] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service*

DECEMBER 1933

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*In.*	*In.*	*In.*
Cape Race, N.F	99												
Sydney, C.B.I	48	29.86	29.91	+0.02	21.3	−6.9	28.5	14.1	48	−10	3.71	−0.92	17.5
Halifax, N.S	88	29.68	29.79	−.17	21.6	−6.0	29.8	13.3	46	−10	3.67	−1.45	9.0
Yarmouth, N.S	65	29.86	29.93	−.05	25.3	−5.4	32.5	18.1	45	−8	8.19	+3.42	70.2
Charlottetown, P.E.I	38	29.86	29.90	−.04	16.3	−8.0	24.0	8.7	42	−17	5.24	+1.58	45.6
Chatham, N.B	28	29.84	29.88	−.06	6.7	−10.3	16.0	−2.7	30	−30	4.44	+1.22	44.4
Father Point, Que	20	29.99	30.02	+.07	6.4	−9.0	13.6	−.7	32	−26	2.11	−.72	21.1
Quebec, Que	296	29.74	30.08	+.07	7.2	−8.0	14.9	−.5	36	−32	3.05	−.64	30.5
Doucet, Que	1,236				−7.6		5.6	−20.7	33	−56	3.25		32.3
Montreal, Que	187												
Ottawa, Ont	236	29.84	30.13	+.11	8.8	−8.2	18.2	−.6	40	34	4.81	+1.90	29.1
Kingston, Ont	285	29.77	30.11	+.07	16.8	−6.9	24.5	9.2	45	−30	3.24	.00	12.4
Toronto, Ont	379	29.67	30.10	+.05	24.2	−2.8	31.5	16.9	50	−22	2.97	+.06	18.8
Cochrane, Ont	930				−4.2		5.8	−14.2	37	−41	1.94		19.3
White River, Ont	1,244	28.68	30.08	+.11	−1.8	−11.5	12.1	−15.7	38	−55	2.76	+1.05	26.4
London, Ont	808				24.3		31.1	17.5	53	−10	3.54		15.4
Southampton, Ont	656	29.34	30.07	+.05	22.8	−3.9	29.0	16.7	47	−15	4.42	+.44	32.4
Parry Sound, Ont	688	29.36	30.10	+.09	14.7	−6.5	23.0	6.5	41	−34	3.79	−.69	23.7
Port Arthur, Ont	644	29.38	30.13	+.14	5.5	−7.7	14.1	−3.1	38	−28	1.33	+.46	12.8
Winnipeg, Man	760	29.27	30.17	+.15	−4.6	−8.7	5.6	−14.8	40	−42	1.57	+.66	15.7
Minnedosa, Man	1,690	28.19	30.14	+.12	−5.1	−10.8	4.3	−14.4	36	−44	1.41	+.79	14.1
Le Pas, Man	860				−18.2		−10.8	−25.6	16	−50	2.00		20.0
Qu'Appelle, Sask	2,115	27.66	30.06	+.06	−.2	−7.6	9.6	−9.9	47	−33	1.34	+.82	13.4
Moose Jaw, Sask	1,759							−8.2	52	−30	1.97		19.7
Swift Current, Sask	2,392												
Medicine Hat, Alb	2,365	27.36	29.96	−.01	8.7	−9.5	17.0	.4	57	−22	1.91	+1.36	19.1
Calgary, Alb	3,540	26.09	29.98	+.04	3.1	−15.1	11.9	−5.7	56	−26	1.28	+.69	12.8
Banff, Alb	4,521												
Prince Albert, Sask	1,450	28.50	30.20	+.19	−7.4	−10.2	4.1	−18.9	25	−45	1.61	+.87	16.1
Battleford, Sask	1,592	28.27	30.15	+.16	−8.7	−14.1	−1.6	−15.8	−2	−16	1.50	+1.18	15.0
Edmonton, Alb	2,150												
Kamloops, B.C	1,262												
Victoria, B.C	230	29.54	29.80	−.17	41.8	+.6	45.2	38.4	56	30	11.20	+3.22	8.6
Barkerville, B.C	4,180												
Estevan Point, B.C	20												
Prince Rupert, B.C	170												
Hamilton, Ber	151	30.00	30.16	+.04	65.7	+1.0	70.3	61.0	77	50	4.10	−.39	0

LATE REPORTS FOR NOVEMBER 1933

Cape Race, N.F	99				35.9		42.6	29.3	55	13	7.75		0.5
Sydney, C.B.I	48	29.78	29.83	−0.12	33.1	−4.0	40.9	25.4	58	14	6.69	+1.25	5.5
Halifax, N.S	88	29.58	29.69	−.32	34.4	−2.9	42.9	25.9	55	14	5.80	+.14	.2
Yarmouth, N.S	65	29.76	29.83	−.19	36.1	−3.8	42.8	29.4	58	18	5.13	+.64	19.6
Charlottetown, P.E.I	38	29.76	29.80	−.16	29.8	−5.7	36.4	23.1	55	13	4.57	+.60	27.1
Chatham, N.B	28	29.72	29.75	−.22	24.3	−6.7	34.1	14.5	58	−12	3.26	−.49	17.6
Doucet, Que	1,236				9.8		19.7	0	56	−30	4.73		37.1
London, Ont	808				32.0		38.9	25.2	74	4	4.76		22.8
Banff, Alb	4,521	25.43	30.09	+.13	34.2	+8.4	40.5	27.8	49	9	.44	−1.83	2.4
Kamloops, B.C	1,262	28.93	30.25	+.29	39.8	+6.4	44.4	35.3	58	26	.48	−.98	T
Estevan Point, B.C	20				46.8		50.0	43.7	54	36	12.37		0
Prince Rupert, B.C	170				43.8		48.1	39.5	56	32	25.53		0
Hamilton, Ber	151	29.90	30.06	+.01	69.5	+.8	74.0	65.0	79	58	4.02	−.36	0

SEVERE LOCAL STORMS, DECEMBER 1933

[Compiled by MARY O. SOUDER]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Texarkana, Ark	2				$1,000	Rain and electrical.	Damage to courthouse	Official, U.S. Weather Bureau.
Crossett, Ark., 3 miles east	5	6:30 p.m.	100-400		8,000	Tornado	5 persons injured, 1 seriously; property damaged	Do.
Shreveport, La., 6 miles north	5	do	[1] 1		7,000	do	5 persons injured; buildings damaged	Do.
Robeline, La., 4 miles west	5	8:30 p.m.		1	10,000	do	Several houses demolished	Do.
Fort Jessup, La	5			1		do	Considerable unestimated damage to several farm buildings.	Do.
Havre, Mont., and vicinity	5					Wind	Wires blown down; damage to buildings, signs, and fences.	Do.
Monmouth, Ocean, Middlesex, and Camden Counties, N.J.	11			2		Snow and sleet	26 persons injured, 1 seriously, as result of accidents.	Do.
Cleveland, Ohio	11	1-9 a.m.				Gale	Highest velocity 46 miles per hour at 4:20 a.m.	Do.
Scranton, Pa	11	A.m.				Snow	Highways icy and dangerous	Do.
Trenton, N.J	13					Rain, sleet, and snow.	6 persons injured; automobiles without chains powerless to move.	Do.
Nooksack to Clearbrook and Sumas, Wash.	13-14				4,000	Ice storms	Telephone and electric service interrupted; orchards damaged.	Do.
Dubuque, Iowa	14	P.m.				Rain and sleet	Wires and streets covered with ice; traffic paralyzed for several hours; walking hazardous.	Do.

[1] Mile instead of yards.

SEVERE LOCAL STORMS, DECEMBER 1933—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Minneapolis, Minn.	14–15	P.m.				Glaze storm	Numerous traffic accidents resulted	Official, U.S. Weather Bureau.
Oklahoma, Panhandle	14					Heavy sandstorm	Visibility reduced to 100 yards, delaying traffic and necessitating the use of artificial light during midday.	Do.
Madison, Wis.	14					Glaze	Streets, sidewalks, and windshields covered with glaze from freezing mist; walking hazardous.	Do.
Milwaukee, Wis.	14			1		Rain and wind	Rain froze as it fell; wires blown down; man killed and 9 persons injured in automobile accidents; 15 pedestrians injured by falling.	Do.
New York City, N.Y.	15	A.m.		3		Snow and sleet	All railroad and motor service interrupted; service abandoned on some elevated lines; at least 3 deaths caused by down-pouring ice; Coast Guard reported that the Hudson River was frozen from Poughkeepsie to Albany trapping 6 cargo-laden ocean freighters in the ice pack.	Do.
Scranton, Pa.	15	do.				Rain and sleet	Rain and sleet froze as it fell; streets and highways in dangerous condition.	Do.
Trenton, N.J.	15	3:10 p.m.				Rain	Rain froze as it fell and formed smooth glaze causing motorists and pedestrians to experience difficulty; 6 persons seriously injured.	Do.
Buffalo, N.Y.	15					do	Rain froze as it fell causing unusually slippery conditions resulting in numerous accidents and much delay in traffic.	Do.
Havre, Mont.	16–17	P.m.				Wind	Wind drifted the loose snow having a blinding effect on persons out-of-doors; travel suspended on side roads; traffic seriously impeded on highways by snowdrifts; trains many hours late.	Do.
Shreveport, La., 10–15 miles northwest.	17	8:15–8:30 a.m.	100	4	9,000	Tornado	19 persons injured; buildings damaged; slight damage to crops and timber; path 8 miles long.	Do.
Aberdeen and Hoquiam, Wash.	17					Flood and gale	An 11-foot tide accompanying a tremendous downpour of rain; business districts flooded; on banks of the Chehalis River all available small boats were rushed to rescue of families marooned in their homes.	Do.
Chimacum, Wash.	17					Ice storm	Damage to telephone and electric lines and to orchards; damage from this storm included in estimate of storms on 13–14th at Nooksack to Clearbrook and Sumas.	Do.
Walla Walla, Wash.	17				500	Wind	Telephone and transmission wires and several large trees blown down.	Do.
Sixprong, Wash., and vicinity	18					Gale	Damage to buildings and roofs	Do.
Walters, Okla.	18–19					Glaze and sleet	Damage to utility lines; amount not estimated	Do.
Buffalo, N.Y.	20					Snow and glaze	Stormy conditions in the afternoon, when snow fell causing traffic delays and several accidents.	Do.
Binghamton, N.Y.	20–21					Snow and ice	Motorists and pedestrians found traveling hazardous.	Do.
Helena, Mont.	21					Wind	Wind was especially severe, reaching a corrected maximum velocity of 48 miles per hour at 8:17 p.m., highest velocity ever recorded at Helena during any December.	Do.
Shoshone County, Idaho	3d week				200,000	Excessive rain and flood.	Considerable damage to highways, railroads, and private property.	Do.
Havre, Mont.	23	8:15 a.m., 1:45 p.m.				Wind and snow	Blizzard conditions prevailed; new snow was blown violently about the streets and open prairie; visibility in town ½ to 1 block.	Do.
Chicago, Ill.	25–26			6		Snow	Snow and ice covered streets impeding traffic; 6 deaths due to exposure; 113 snowplows kept busy all night of 25th.	Do.
New Haven, Conn.	26					do	10 inches of snow fell; much trouble to traffic; roads blocked.	Do.
Michigan City, Ind., and South Haven, Mich.	26			8		Wind and snow	2 fishing tugs capsized and the crews drowned	Do.
Boston, Mass., and vicinity	26			3		Snow and sleet	Almost a foot of snow fell in Boston; trains from New York and west running an hour late at 8 p.m. and terminal congestion had disorganized commuting trains; 3 deaths in Boston attributed to the storm.	Do.
Cleveland, Ohio	26	12 p.m., 8 a.m.				Heavy snow	Depth of snow 2.3 inches	Do.
Rochester, N.Y.	26–27					Snow	9 inches of snow fell causing little interruption to traffic.	Do.
New York City, N.Y.	26–30					do	10 inches of snow fell; streets slippery; 50 or more persons died of exposure and several hundred treated because of low temperature; sleighing and skating in and around the city for 4 days; sleet on 3 days and glaze on 4 days.	Do.
Scranton, Pa.	29–31			1		Snow and sleet	Minimum temperature −10 on 29th; Western Union reported all wires to New York out due to snapping from cold; morning weather reports over an hour late coming from New York; one death due directly to cold on the 30th.	Do.
San Gabriel Drainage Basin, Calif.	31			44		Torrential rains	Rain caused the death of 44 persons in San Gabriel Drainage Basin; much damage occurred in portions of Los Angeles, County.	Do.

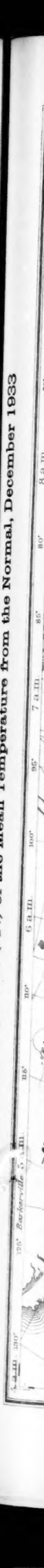


Chart I. Departure (°F.) of the Mean Temperature from the Normal, December 1933

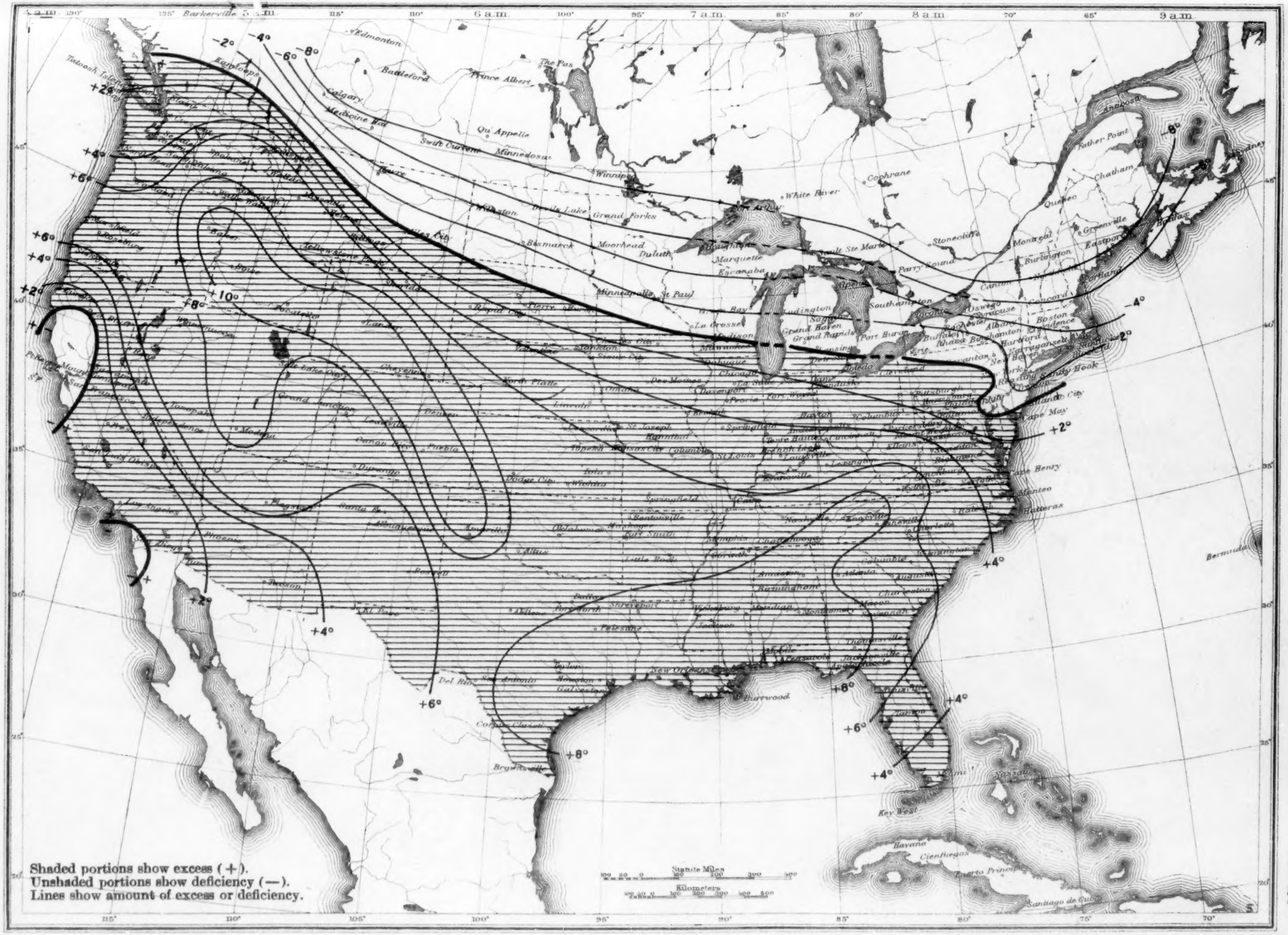
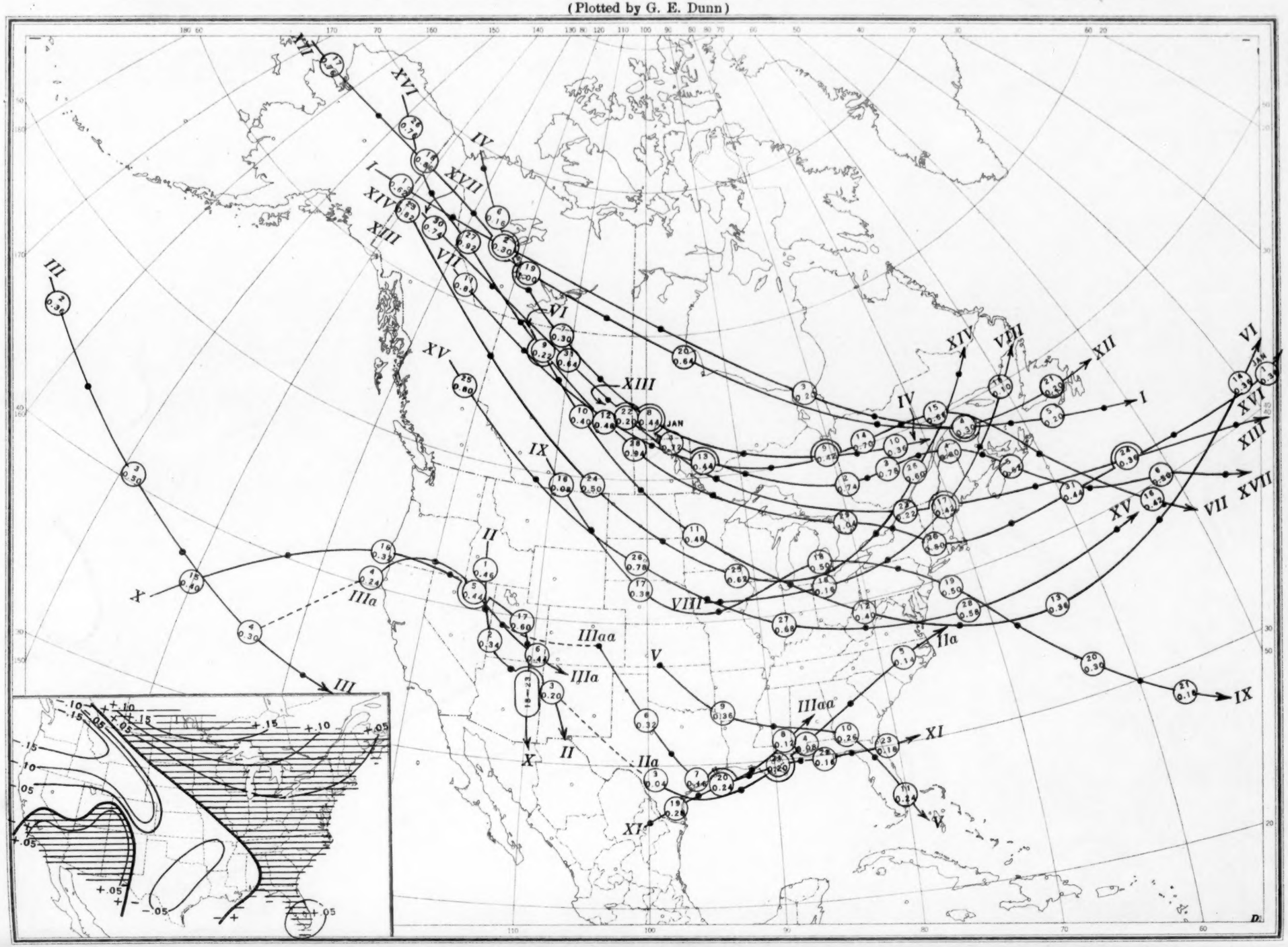

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, December 1933. (Inset) Departure of Monthly Mean Pressure from Normal

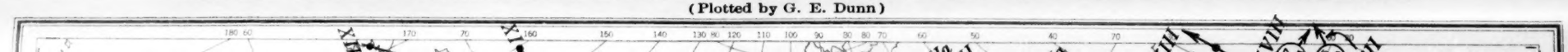
(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, December 1933. (Inset) Change in Mean Pressure from Preceding Month

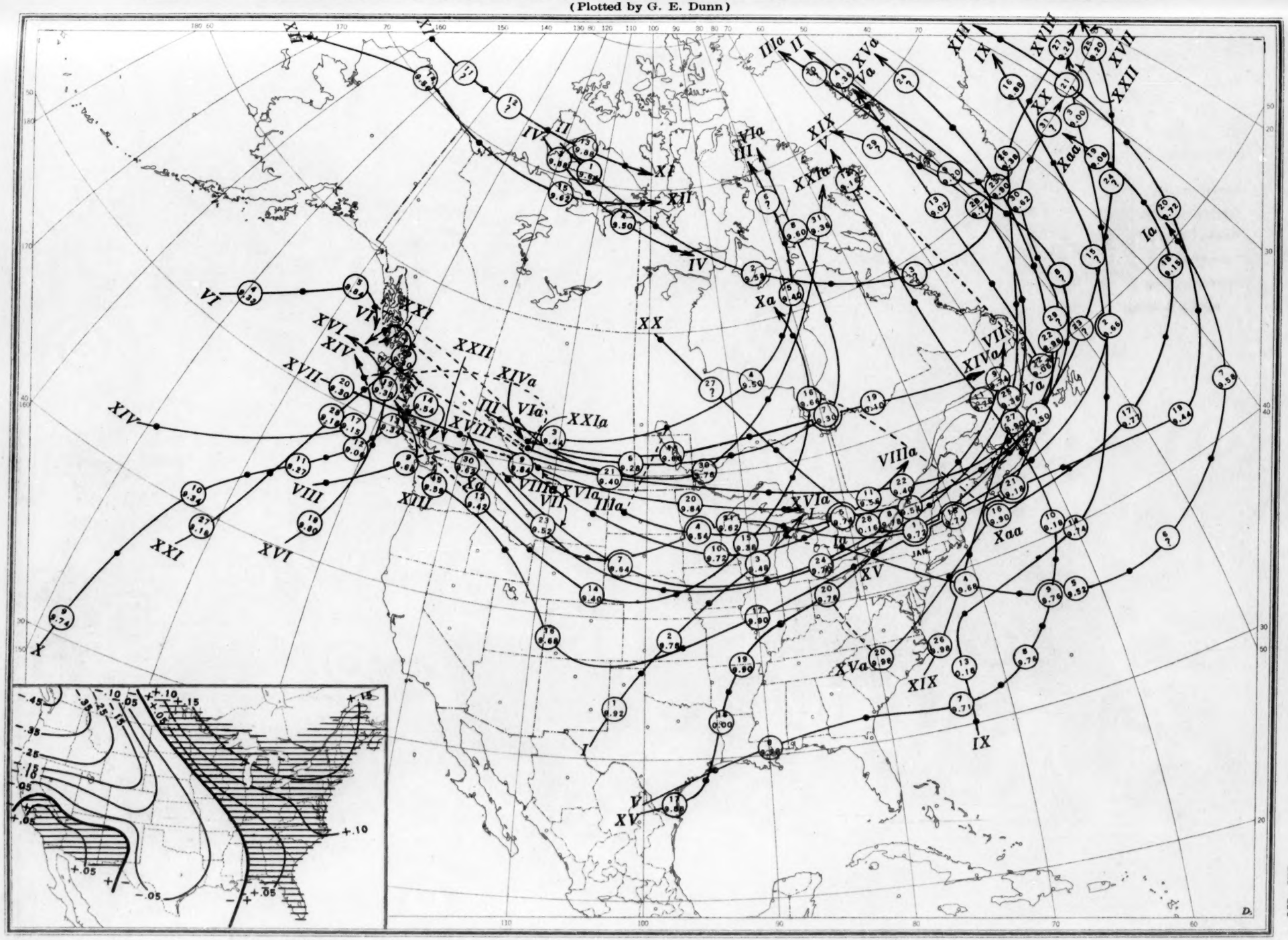
(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, December 1933. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, December 1933

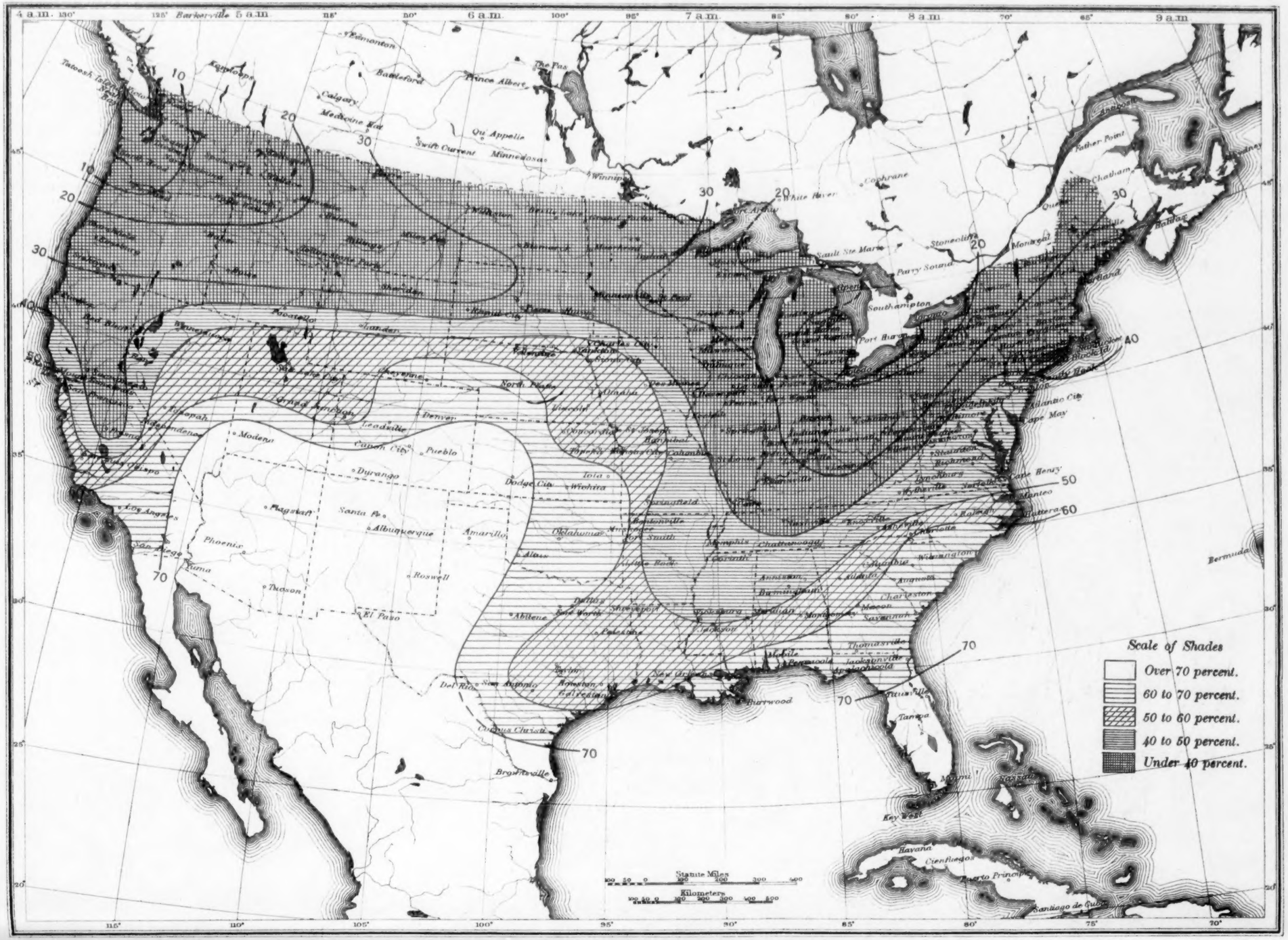


Chart V. Total Precipitation, Inches, December 1933. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, December 1933. (Inset) Departure of Precipitation from Normal

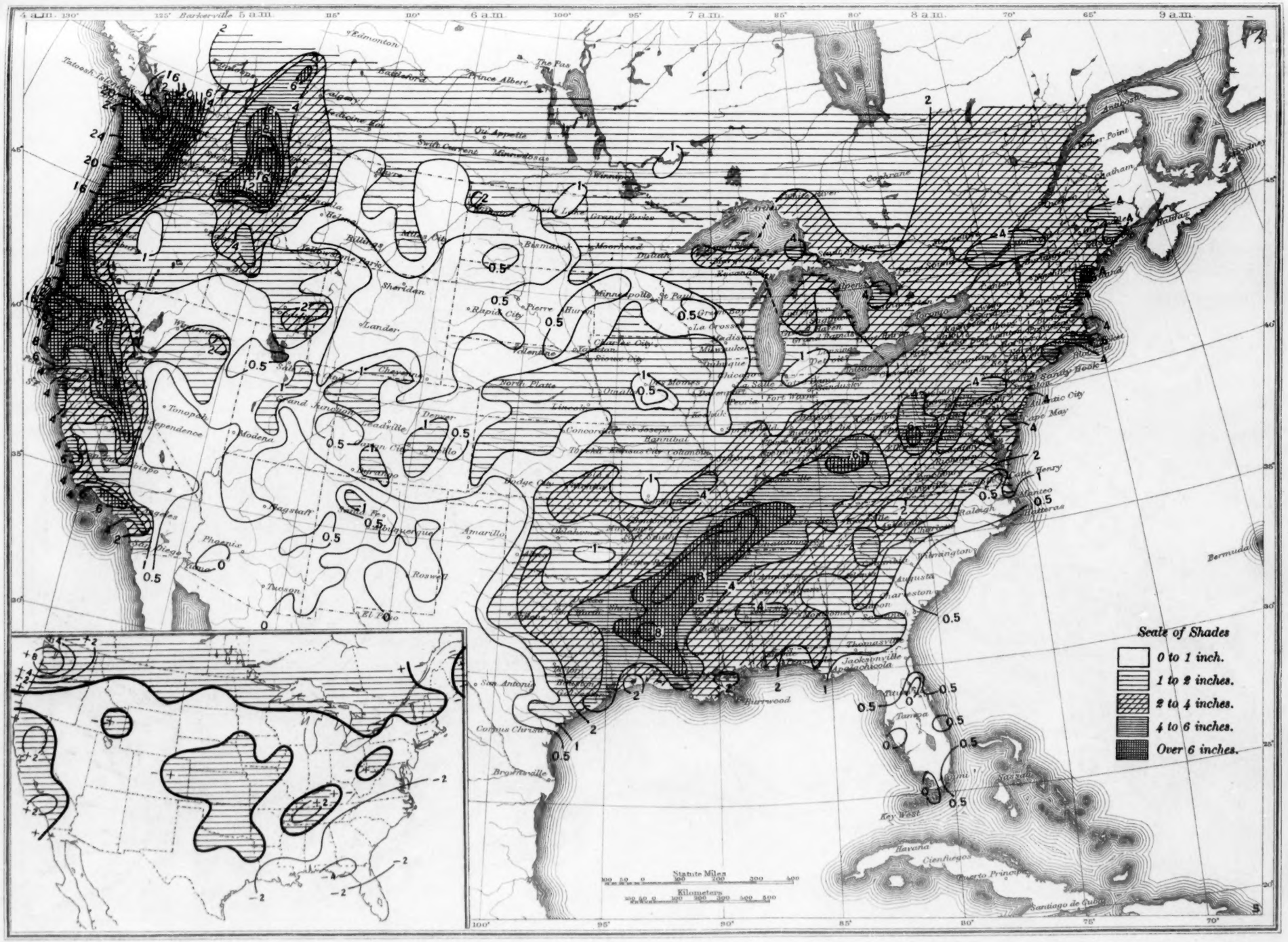


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, December 1933

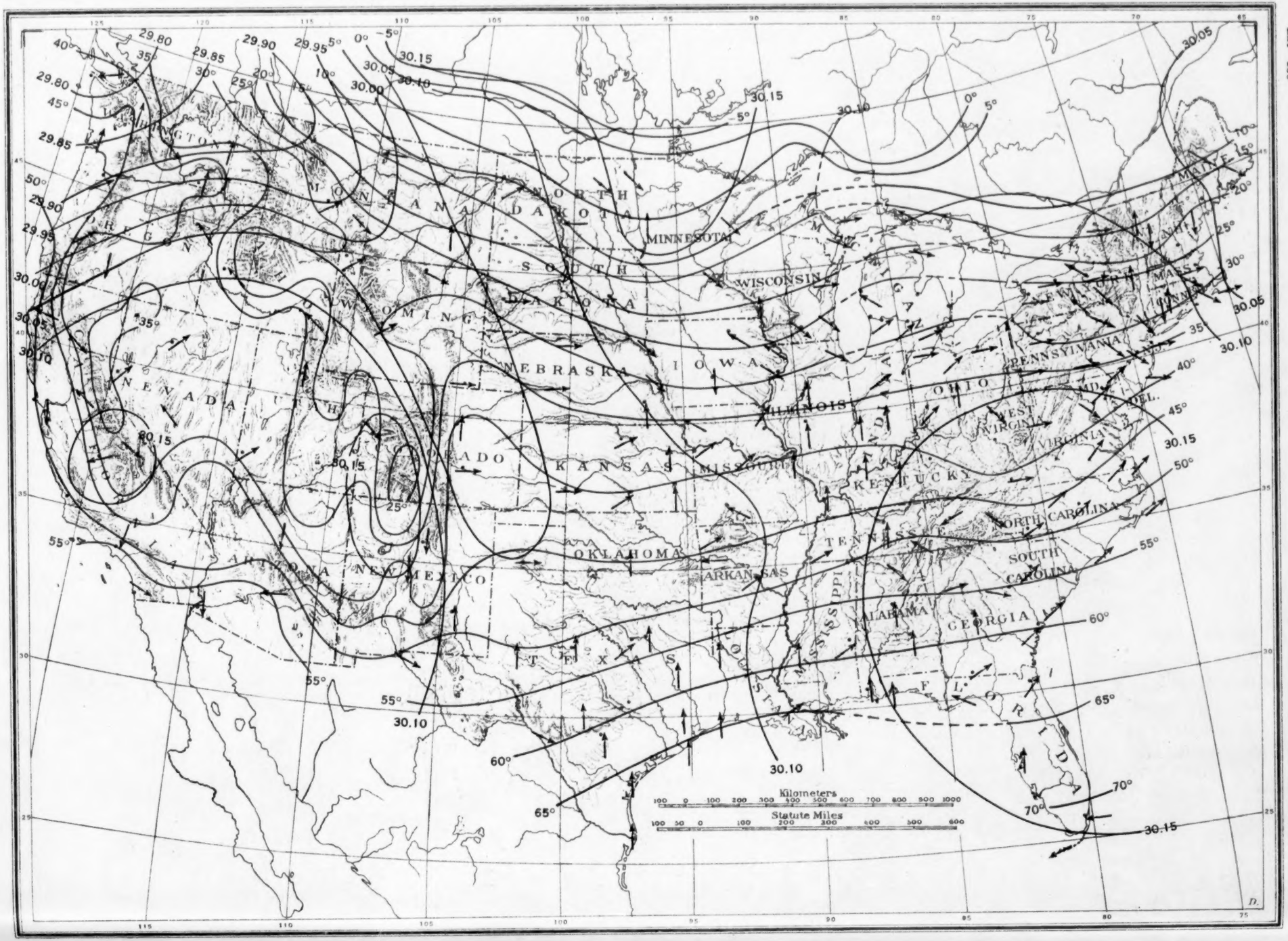


Chart VII. Total Snowfall, Inches, December 1933. (Inset) Depth of Snow on Ground at 8 p. m., Monday, January 1, 1934

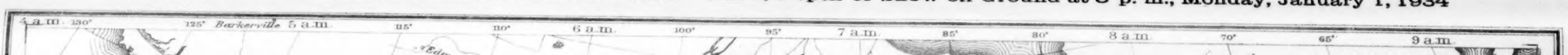


Chart VII. Total Snowfall, Inches, December 1933. (Inset) Depth of Snow on Ground at 8 p. m., Monday, January 1, 1934

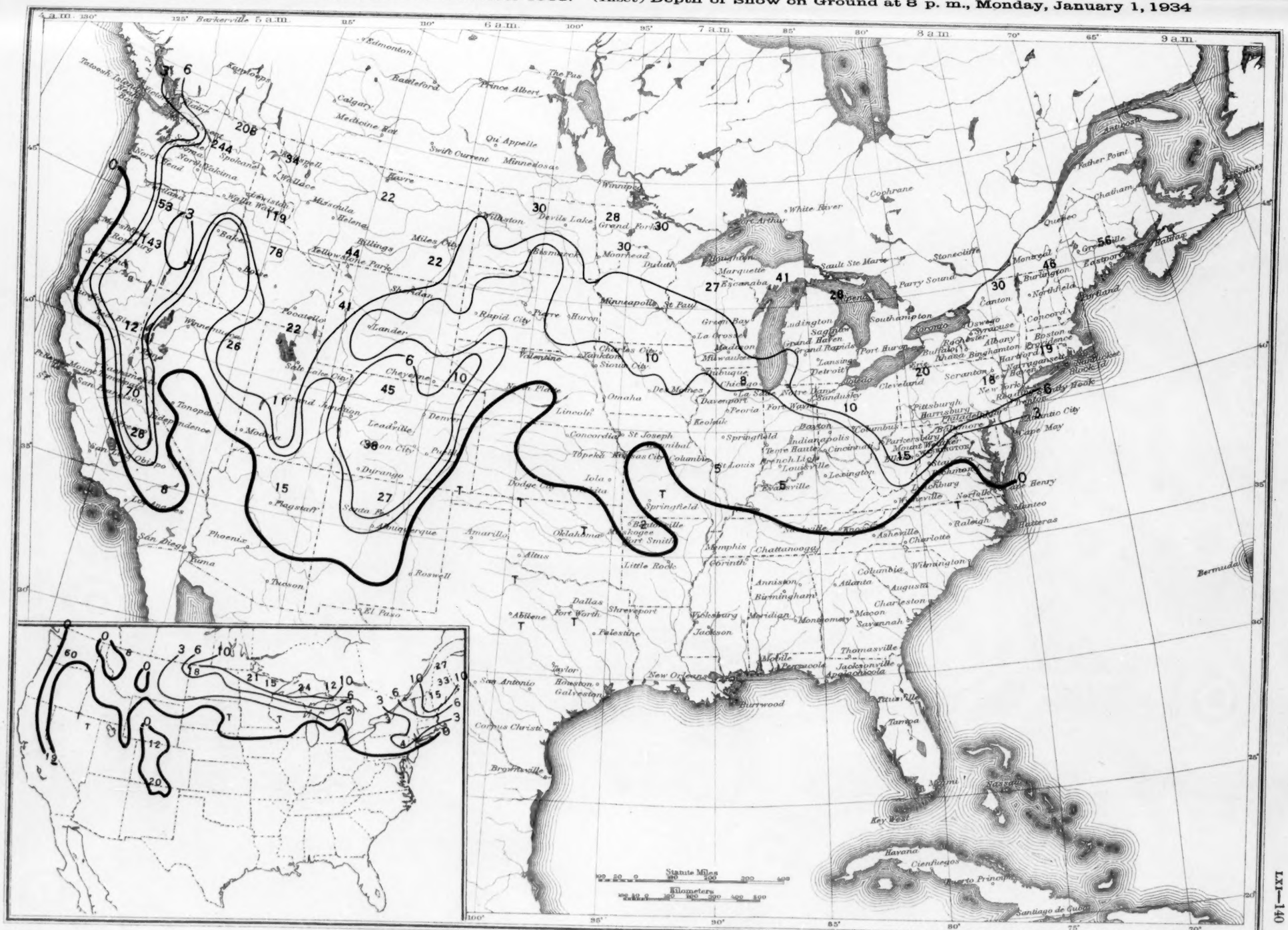


Chart VIII. Weather Map of North Atlantic Ocean, December 1, 1933
(Plotted from the Weather Bureau Northern Hemisphere Chart)

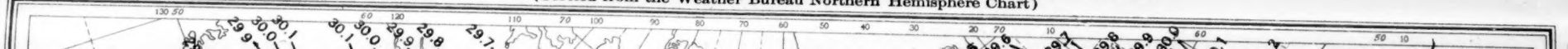
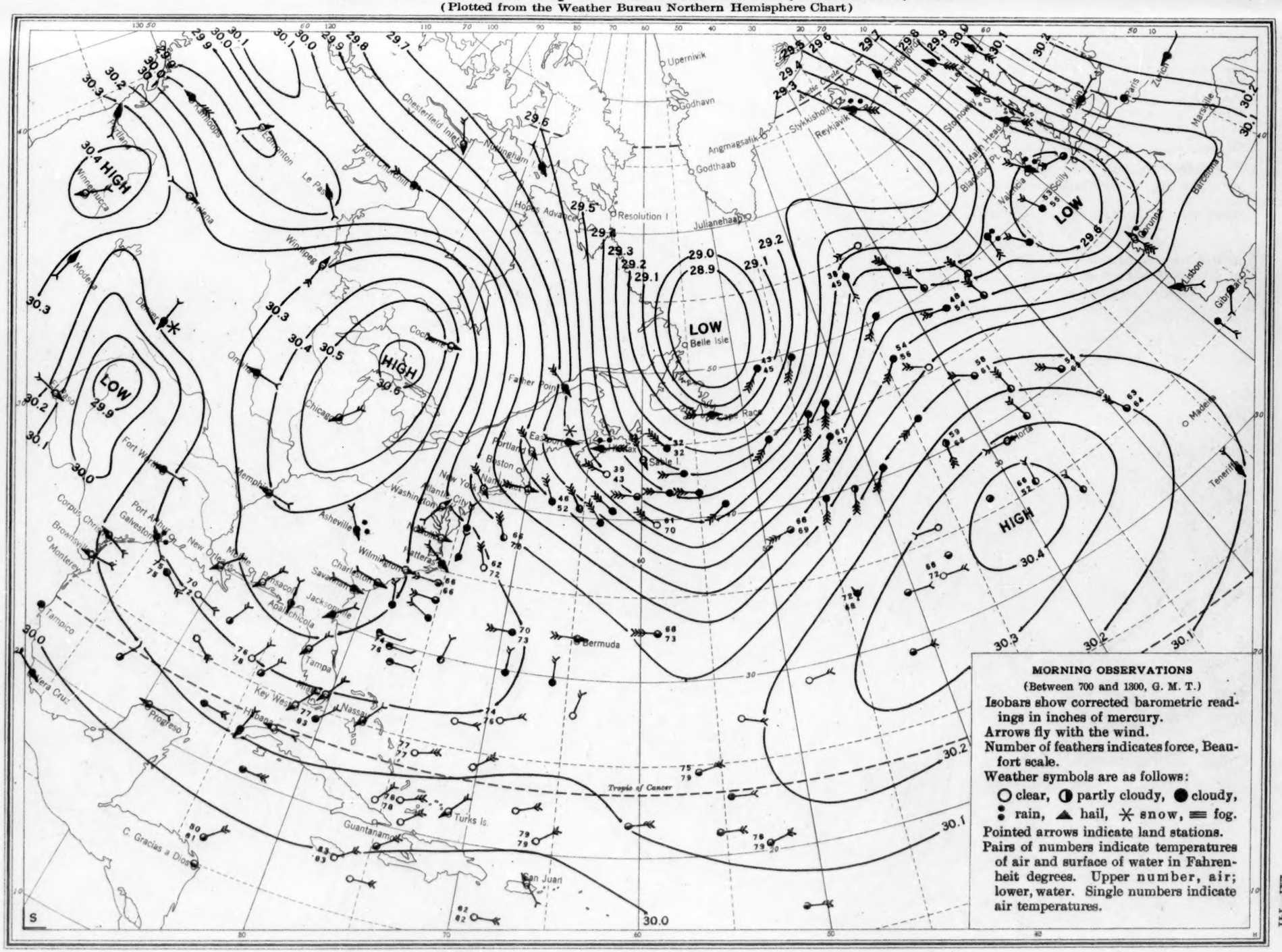


Chart VIII. Weather Map of North Atlantic Ocean, December 1, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicates force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail, ✳ snow, 〓 fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart IX. Weather Map of North Atlantic Ocean, December 2, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)

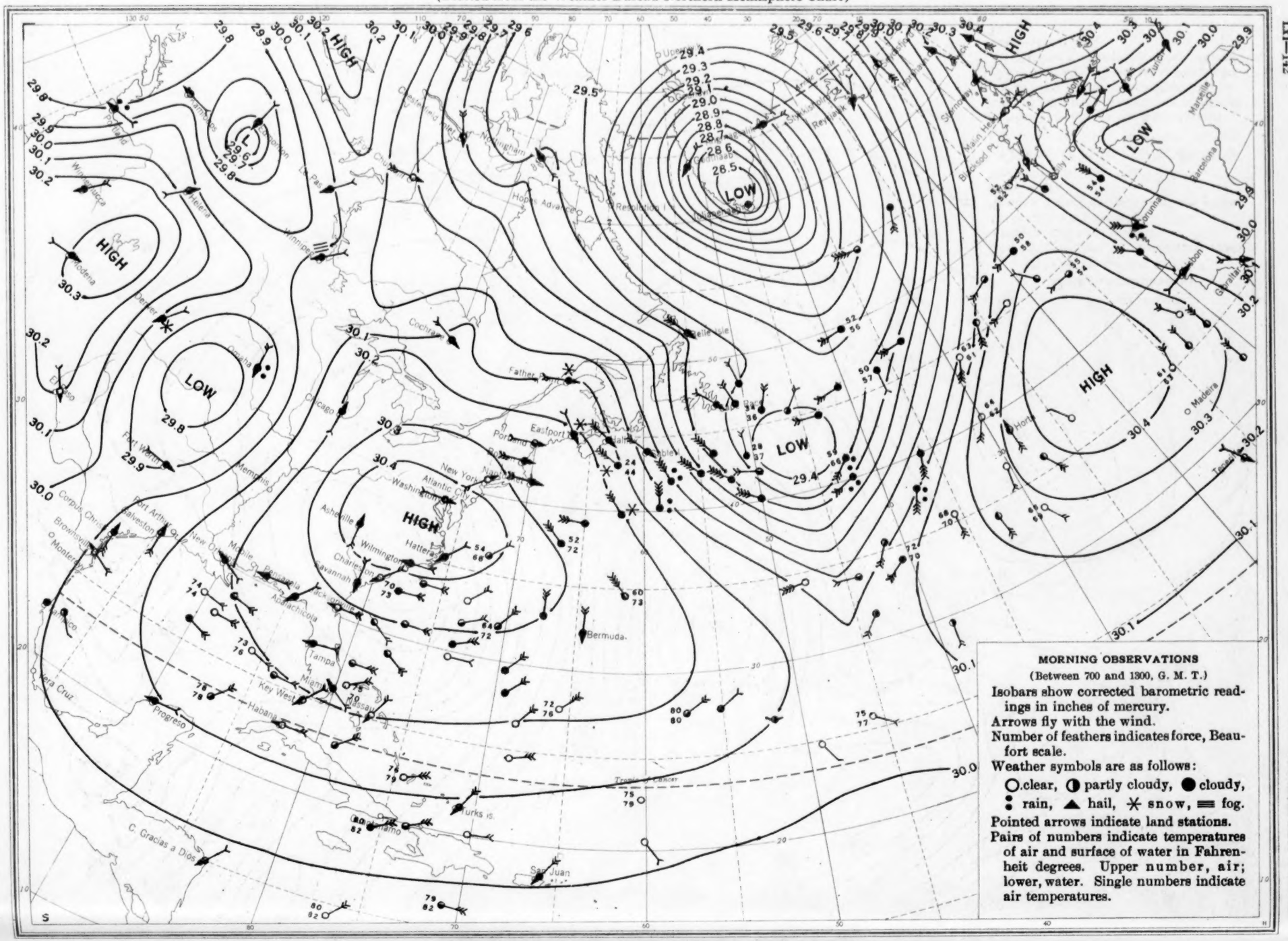

HIGH
LOW
MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicates force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
• rain, ▲ hail, ✳ snow, ≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart X. Weather Map of North Atlantic Ocean, December 11, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)

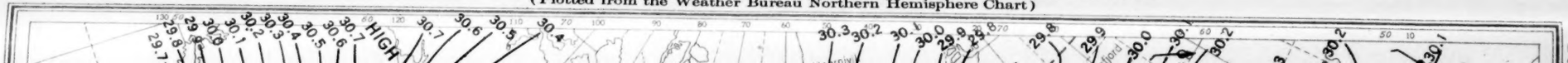


Chart X. Weather Map of North Atlantic Ocean, December 11, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)

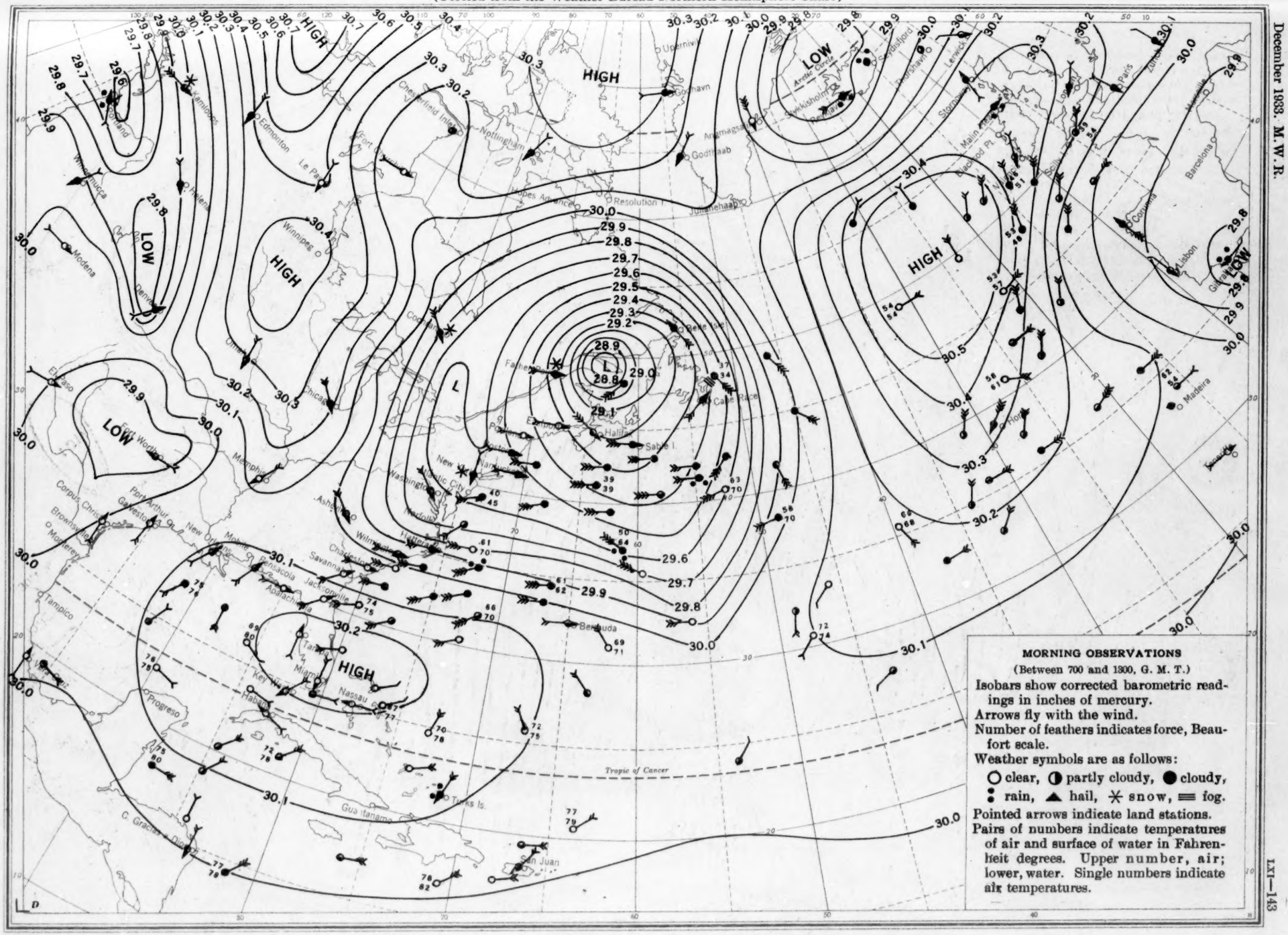
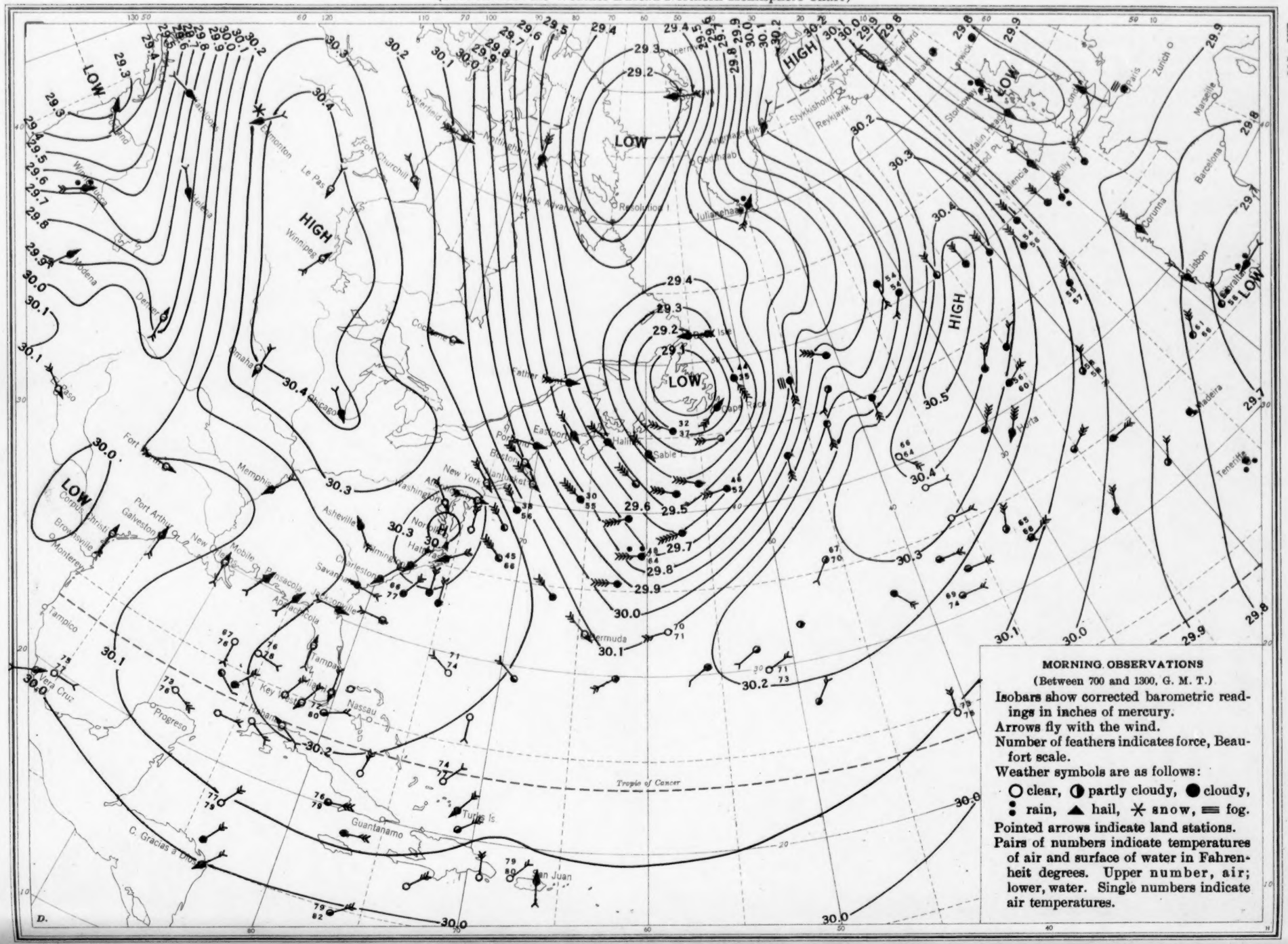

HIGH
LOW
L
Tropic of Cancer
MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicates force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail, snow, fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

Chart XI. Weather Map of North Atlantic Ocean, December 12, 1933

(Plotted from the Weather Bureau Northern Hemisphere Chart)


LOW
HIGH
Tropic of Cancer
MORNING OBSERVATIONS
(Between 700 and 1300, G. M. T.)
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicates force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
⋮ rain, ▲ hail, ✳ snow, 〓 fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.

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